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THE FIRST CHINESE STUDENT SPACE SHUTTLE GETAWAY SPECIAL PROGRAM

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Abstract

The first Chinese Getaway Special program, including program organization, student proposal evaluation procedure, contents of some of the finalists' experiments, will be presented. Specifically, the two experiments selected for the eventual flight on the Space Shuttle will be described in detail.

1.0 The Chinese GAS Program

The first Chinese student US space shuttle getaway special (GAS) program was jointly organized and sponsored by American Association for Promotion of Science in China (AAPSC), a Los Angeles-based nonprofit organization, and Chinese Society of Astronautics (CSA), based in Beijing, China. The agreement was signed on December 27, 1985 in Beijing, China. The call for proposals from vast population of Chinese secondary school students, estimated at 150 millions strong, was announced in January 1986. Over seven thousand proposals were submitted before the end of summer, in spite of the demoralization caused by the Challenger disaster. Those proposals were evaluated by a two-tier process. First, the proposals were presented and defended orally by student proposers at nine regional locales approximately evenly distributed throughout China. Those regional symposia, actively participated by six experts from the States and many of their Chinese counterparts, produced a total of 264 regional proposals for further consideration in the national symposium to be held during the Christmas season of 1986, in Beijing, China. The national proposal

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evaluation committee consisted of seven American and twenty-five Chinese experts whose specialties covered a broad range of space science and technology disciplines.

The criteria that they had applied uniformly throughout the entire selection process were based on the proposal creativity, scientific merits, experiment feasibility and organization. The committee certainly went through quite a difficult time in deciding what to accept or decline. Nevertheless, twenty proposals were selected as the national finalists. Those proposals, as well as those not chosen, were generally of surprisingly good quality considering the severe handicap that the Chinese students must cope in search for information needed for the research topic. The titles for those twenty proposals are:

1. Control of debris in the cabin of space shuttle, by Wang Nian-qing
2. Solidification of two immiscible liquids in space, by Tian Chun-Liang
3. Effect of cosmic ray on pharmaceutical products, by Shi Gang
4. Effect of µg on plant cell reproduction, by Zhao Quan-Zhong
5. Effect of µg on onion cell reproduction, by Tian Yu-Zhi
6. Application of Velcro in space, by Wang Hai-jiang
7. Observation of surface tension under µg, by Zhou Yan
8. Effect of µg on germinatn of Chinese herb seeds, by Huang Zheng-Chong
9. Ice formation at different temperatures under µg, by Liu Zhong
10. Healing worm injury under µg, by He Kai
11. Mixing paraffin, water and ice under µg, by Zhu Lei
12. Speeding up chemical reactions under µg, by Huang Wen-Ge
13. Gas and liquid phase separation under µg, by Liu Shu-Xiang
14. Coating and capillary absorption under µg, by He Bin
15. Making Tofu in space, by Zhan Han-Jing
16. Behavior of NaCl solution droplet in E field under µg, by Song Yang
17. Property of liquid crystal under µg, by Zhang Jin-Song
18. Effect of µg on Chinese painting, by Zhang Qin-Mei
19. Effect of µg on germintn./reprod. of Chinese mushroom, by Shen Zhong
20. Feathered Ying-luo plant growth in space, by Jiang Yong-Bo

The first two(#1 and 2) experiments were further designated, after hours of heated debate among committee members and final settlement with a secret balloting, as the first Chinese student microgravity payload for a future US space shuttle flight. The third proposal was selected as the back-up. The hardwares for carrying out the GAS experiments are in the process of being developed and fabricated by Beijing Institute of

Environment Test Engineering(BIETE). The qualification for flight in space shuttle is scheduled to complete in the second quarter of 1988.

To commemorate this event, a logo has been designed (Fig. 1). The lone star in the sky of the Great Wall signifies that it is the first such event in China.

Figure 1. The logo to commemorate the Chinese student space shuttle getaway special program. The lone star in the sky of the Great Wall signifies the first such event in China.

2.0 Student Experiments

Experiment 1: **"The control of debris in the cabin of space shuttle,"** by Wang Nian-Qing

The purpose of the experiment is to study the motion of debris (small particulates) in the cabin of shuttle under the microgravity condition. A certain amount of simulated particulated debris are stored in a container, a side wall of which is covered with a sheet of adhesive paper. A movie camera will be mounted in the container to photograph the motion of debris upon their release in the microgravity environment and to record the moment when they make contact with the side wall and are captured. From a practical point of view, this simple technique could be applied to

remove floating particulates from the living environment in space. In addition, the particulates rely on the residual gravity to initiate the movement. The mathmatical modelling of the experiment could be related to the pseudo-random walk problem. It is highly probable that the residual magnitude of the gravitational field on the shuttle can be backed out from the statistical measurement of those particulate movements.

Experiment 2: **"The solidification of two immiscible liquids in space"** by Tian Chun-Liang

Two immiscible low melt-point materials (Wood's metal and paraffin) will be premixed in various ratios and manners in the solid form on earth and remelted in space, then left to cool and resolidify. It is predicted that paraffin and Wood's metal be phase separated and assume amorphous and crystalline structures, respectively. Depending on the magnitude of the residual gravitational field in the shuttle, the two phases may be uniformly mixed or droplets of the same species may coalesce to form large conglomerates due to the nature tendency for a physical system to minimize its total internal free energy. The samples are to be post-flight analyzed.

3.0 Experimental Apparatus

3.1 Size and weight of the payload: 2.5 cubic feet, 60 pounds.

3.2 Experiment description:

Experiment 1: In this experiment 25 small lumps of different materials to be used as "space debris" or "particulates" will be stored in a container. A side wall will be coated with adhesive cloth. An 8 millimeter movie camera will be installed to view the adhesive wall, to photograph the motion of those small bits of debris after being released under microgravity conditions, and to record the moment when they make contact with the wall. It is desired that every collision of a particulate with the adhesive wall will result in a capture by the wall. However, this is not a prerequisite for the success of the experiment. The camera will be controlled and pictures will be taken at a preprogrammed time sequence. The container will be maintained intact for further post-flight analyses.

Experiment 2: 8 small cylindrical containers, each 2 cm in diameter and 6 cm in height, will be loaded with paraffin and Wood's metal mixtures in

different ratios and manners. The two heaters are of foil-type, each powers 4 cylinders. The heating and cooling sequence are preprogrammed. Those containers will be left intact after the space experimentation so that they can be post-flight analyzed.

3.3 Supporting Structure

To provide added thermal insulation, the entire experimental apparatus will be housed in foam/fiberglass composite shells within the GAS canister. These hexagonal type structures are the same as the "spacepak" used in the similar payload in the past GAS flights. Experiment #1 will be stacked on top of the Experiment 2 in a two-spacepak configuration.

The spacepaks will be held by three sets of aluminum ribs on the exterior. At one end of the rib assembly is an aluminum ring with bolt holes for securement to the experiment mounting plate. At the opposite end of the rib assembly, there are three separate bumpers to provide lateral support of the payload within the container.

Figures 2 and 3 show the top view of those two experiments. Each

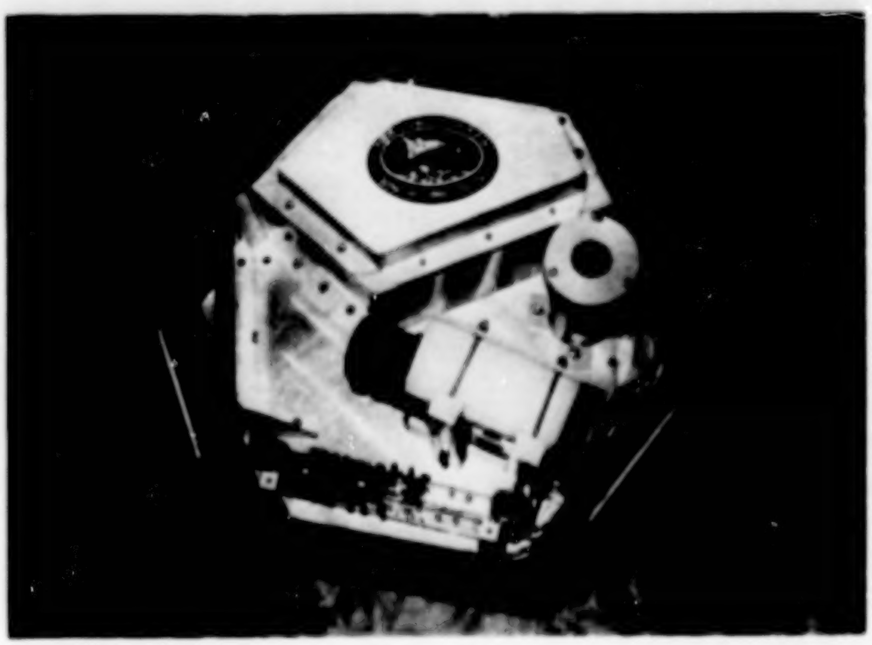

Figure 2. Top view for experiment #1. Initially, the debris are confined inside the right half of the chamber (marked by the logo) by a partition to slide open in the orbit.

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experiment has its own controller and power supply. All batteries are installed in the second spacepak.

3.4 Controllers and Power Supplies

Two controllers, one per spacepak, are used to sequence various functions to be performed in the experiments and to record data from analog sensors. It is 65Co2-based microcomputer with 8K RAM, 16K ROM and 32K EPROM. All the programs and all the data collected are stored in EPROM. This same type of controller has been used in several previous GAS payloads of the Utah State University by Professor Rex Megill and his students.

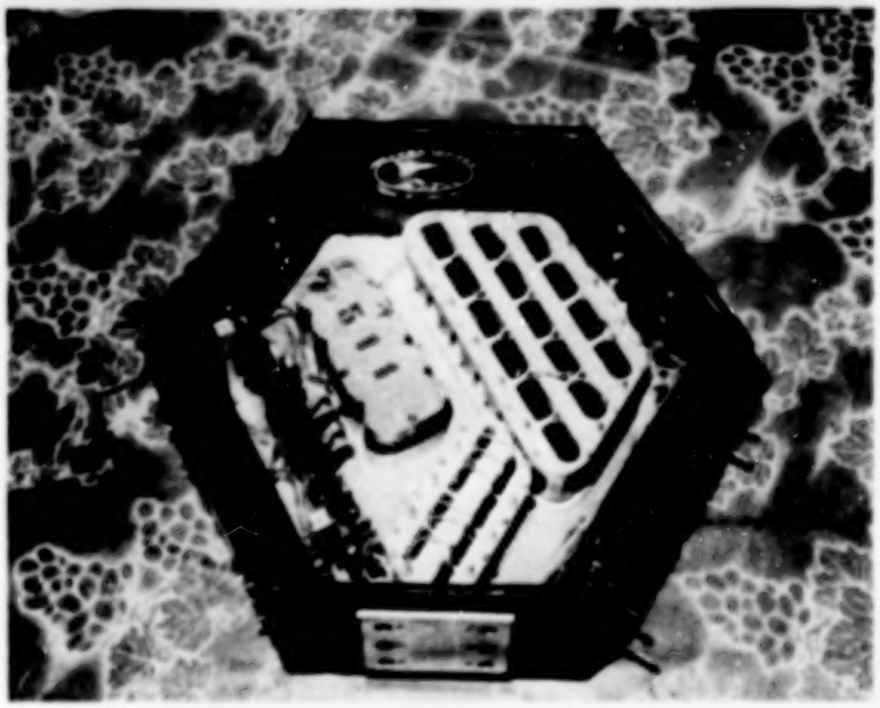

Figure 3. View for experiment #2. Eight small cylinders containing solid mixtures of paraffin and Wood's metal in different ratios and manners are installed under the cover marked by the number 511.

Each spacepak will have two separate power supplies to power the controller and to operate all other electrical devices in the spacepak, including all electronic interface circuitries to the controller. The batteries to be used are rechargeable lead-acid Gates X-cells or D-cells wired in series.

3.5 Operational Scenario

After the shuttle enters the orbit, relay "A" will be turned on at 70,000 feet by a baroswitch automatically. This action sends power to the controller which initiates the controller program sequencing. The controller will wait 2 hours before activating any of the devices in the payload.

In experiment 1, the controller will activate the torque motor to strip off the protective film from the adhesive wall, then the debris will be released and photographed at predetermined time intervals. In experiment 2, the controller will switch on the heater circuits, monitor temperatures and switch them off when the temperature reaches the predetermind value.

4.0 <u>Development of the Payload</u>

4.1 Preliminary Design Phase

Both Wang Nian-Qing and Tian Chung-Liang participated actively in the preliminary design phase of their experiments. During the same time period, they have carried out, thanks to the assistance of the scientists and engineers at BIETE, many ground-based preparatory experiments. Those experiments included: heating and melting the mixture of Wood's metal and paraffin by battery power; taking pictures of debris in order to determine the clarity and resolution of the photography; performing test for selected adhesives, etc.. Data collected from those tests helped to guide the design and fabrication of the engineering prototype for the flight model.

4.2 Flight Model Manufacturing Phase

After numerous modifications and iterations of the engineering prototype, the flight model of the payload has been designed and is being fabricated, which includes:

(1) The spacepak and supporting structures for camera, motor and batteries , etc;

(2) The control system, including printed circuit boards and software;

(3) Foil-type heaters and cylindrical containers;

(4) Assembling;

4.3 Environmental Testing

According to the requirements of experimenter's handbook for GAS payload, environmental testings such as vibration and vacuum thermal test are to be performed on the flight model to demonstrate its compatibility with the space shuttle environments. These tests are in progress and will be completed upon the approval of the phase III Safety Data Package from NASA.

5.0 Acknowledgement

The authors list should include multitude individuals from many Chinese and American sponsoring organizations including, but are not limited to: China Association for Science and Technology, the China Central Television, China Youth News, The China Science and Technology Daily, Science and Technology Center(Los Angeles based), National Association for Chinese American(Los Angeles Chapter) and China Institute of California State University at Northridge. They are indebted to the United Nations for the financial support through the TOKTEN program. They acknowledge Professor Rex Megill of the Utah State University, his colleagues and students for their technical assistance.

Particularly, the authors are profoundly grateful, on behalf of this program, to Dr. Ren Xin-Min and Professor Sun Jia-Dong, of Chinese Ministry of Astronautics, for their unabated support throughout the course of this program.

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Development of *BIO-GAS* Systems

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Abstract

Four experiment systems which have fundamental significances in the field of biotechnology are developed for the Get Away Special(GAS). Unique considerations were necessary to develop the systems which carry out biotechnological experiments under GAS's restricted conditions: - delicate thermal control, fluid handling and protection from contamination. All experimental processes are controlled by internal sequencers and results of the experiments are recorded as images and numerical data within the systems. Our systems are standardized in order to enable repeated use of a variety of experiments by replacement of the experiment modules and modification of experiment sequencing programs.

1. Introduction

Recently, the use of the space environment such as microgravity has been increasingly emphasized. Thermal convection, buoyancy and sedimentation are all strongly affected by gravity and have extremely weak effects in space. Using this phenomenon, high efficiency and purity can be achieved in processing and refinement of materials. This will be most useful in making semiconductors, metallic materials, compound materials, separating and refining medicinal drugs, growing protein crystals and cell culture, for example.

Biotechnology is receiving a great deal of attention with the rapid development of recombinant DNA technology and cellular fusion techniques. Biotechnology is of great significance, not only for its investigations of the phenomena of life, but also for its applications to medicine, agriculture and industry. Space microgravity is also expected to be profitable in this field. We have planned to aproach the space utilization for biotechnology by making use of the opportunity of GAS.

2. Experiment Subjects

We have selected four themes fundamental in biotechnology, and have developed four GAS experiment systems corresponding to these themes. These are detailed below.

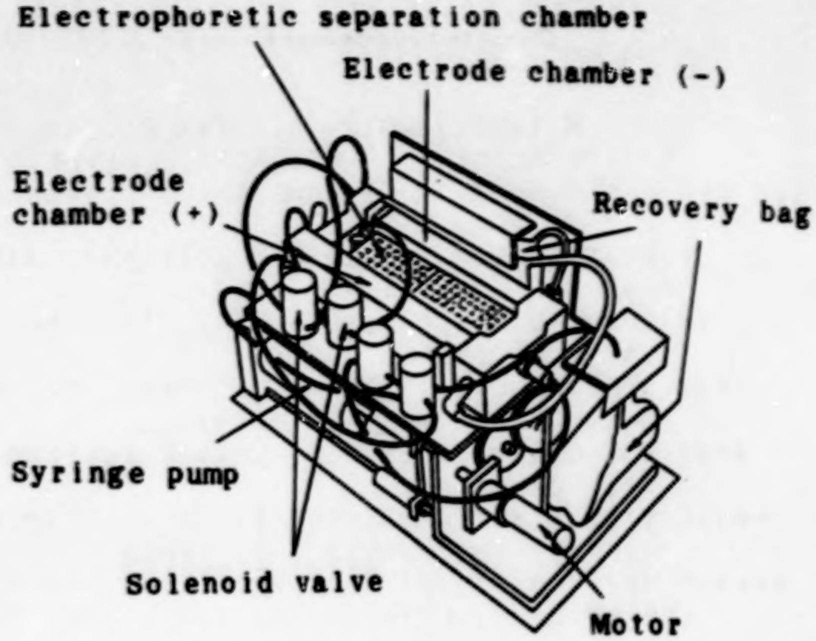

Fig.1 (a) Experiment module of G-456 - Electrophoretic separation of biological materials

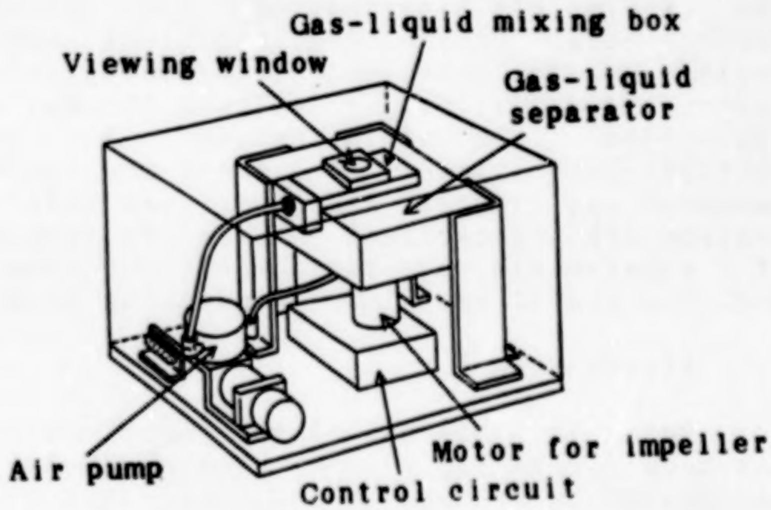

Fig.1 (b) Experiment module of G-457 - Separation of gas bubbles from liquid

G-456: Electrophoretic separation of biological materials

In the microgravity of space, the effects of sedimentation, buoyancy and thermal convection, all of which involve differences in specific gravity, will decrease. Therefore, the ability to separate and refine materials by electrophoresis is being studied, particularly in the area of drug manufacture.

In our experiment, a mixture of enzymes will be separated by electrophoresis in a microgravity environment. A laminar flow of buffer solution is created in an electrophoretic separation chamber, and then, the sample is injected. Voltage is then simultaneously applied to electrodes. The phenomina of this separation are observed by a video camera above the separation chamber and recorded by video cassette recorders. The electrode voltages are 100 V, 200 V, and 300 V. Results of this separation will be compared to results obtained on the earth's surface. Fig.1 (a) shows the drawing of the experiment module of G-456.

G-457: Separation of gas bubbles from liquid

Culturing and fermentation involve the generation of carbon

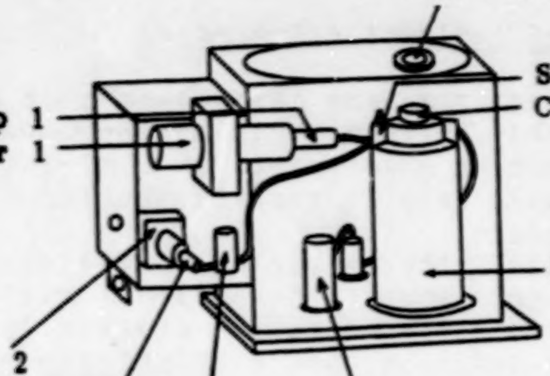

Fig.1 (c) Experiment module of G-458
- Cultivation eellular slime mold

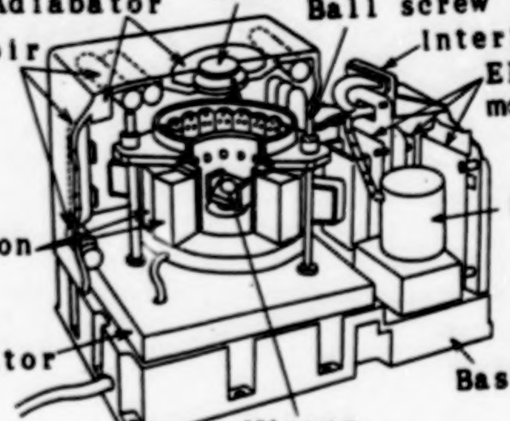

Fig.1 (d) Experiment module of G-459
- Protein crystal growth

dioxide. In a microgravity environment, this gas adheres to living organisms such as yeast and bacteria and the gas interferes with culturing and fermentation, while it can be easily removed from liquid by buoyancy on the earth's surface. Hence, the separating gas from liquid is necessary for culturing and fermentation in space. This technology is related to the development of life-support systems for use in space.

In our experiments, a gas-liquid mixture is placed in a separation chamber. When the blades of the centrifugal separator is rotated, the liquid will gather on the circumference, and gas will collect in the center. The gas in the center will be removed by an air pump, and be injected again into the liguid. The rotating speed of the blades is variable. The movement of bubbles during injection is recorded by a video camera and video cassette recorders to check the separation efficiency. Fig.1 (b) shows the drawing of the

experiment module of G-457.

G-458: Cultivation of cellular slime molds

Evolution of living organisms has occurred in a 1-G environment, however the relationship between their morphogenesis and gravity is not well known. Cultivation experiments in a microgravity environment will yield data that will help to clarify the function of gravity in the evolution of structure.

In our experiments, the culturing of cellular slime mold in a microgravity environment and its development will be recorded by a 35-mm camera to determine the influence of gravity on structure at the cellular-molecular level. We use airtight experiment module with an air atmosphere. Agar is placed in the culture tank, and mixture of water and spores, is prepared separately. Spore cuituring begins with the injection of this mixture into the culture tank. Fig.1 (c) shows the drawing of the experiment module of G-458.

G-459: Protein crystal growth

Convection and sedimentation are weakened in microgravitational conditions. It is thus expected that large, high-quality protein crystals can be obtained in microgravity, then they can be used for 3-dimensional X-ray diffraction analysis. This will help contribute to protein engineering.

The G-459 system has 16 crystallization cells and protein crystals will be grown in microgravity in each cell. The growth will be photographed by a 35-mm camera. The protein crystallization cells are designed for the spontaneous mixing of an ammonium sulfate solution and a protein solution by removing a partition. This experiment will be done using three different methods: batch, free surface diffusion and vapor diffusion. Fig.1 (d) shows the drawing of the experiment module of G-459.

3. System Outline

Concepts

In the development of our experiment systems, the following was considered:

1) Standardization of system is needed to enable repeated use for various kinds of experiments. Electrical subsystems and structures were designed to allow standard use.
2) All experiment systems must conform to the safety and interface requirements for the Space Shuttle established by NASA.
3) All controls, other than turning on of an electrical power source, which is made by a baroswitch, must be done automatically by a sequencer in the system.
4) Results of the experiment must be recorded within the system as images and numerical data. These data will be recovered and analyzed after the return of the Shuttle.
5) Commercially produced components were used as much as possible. However, modifications such as mechanical reinforcement must be made to ensure that NASA's environmental durability requirements are met.

experiment module of G-457.

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Design of Subsystems

Each experiment system consists of the speciallized experiment module and other subsystems which are common for all four systems such as electronics subsystems containing the experiment controllers, recorders and an alarm, a battery assembly and support structures. Fig.2 shows the photograph of the G-459 system. Other three systems have the same configurations.

The experiment systems can be divided into two groups, by the difference in their applicable experiment durations. The G-456 and G-457 have experiment durations of about 30 minutes, and have a relatively small battery capacity, 600 W-hours. Image data of these experiments are recorded by video cassette recorders. The G-458 and G-459 have durations of about 120 hours. For these, the battery capacity is 900 W-hours, and images are recorded by a 35-mm camera. Except for these differences, our experiment systems are standardized as much as possible. Researchers can select the most appropriate system type for their experiment. Fig.3 is a block diagram of the G-459 system, which is common to all four systems except for image observing and recording subsystem. Common design

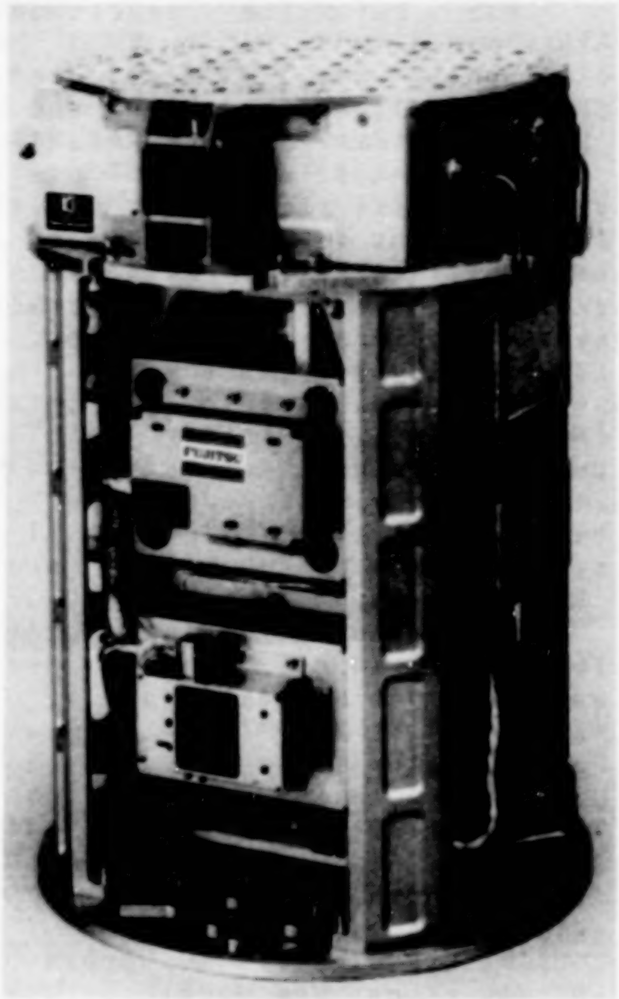

Fig.2 G-459 system

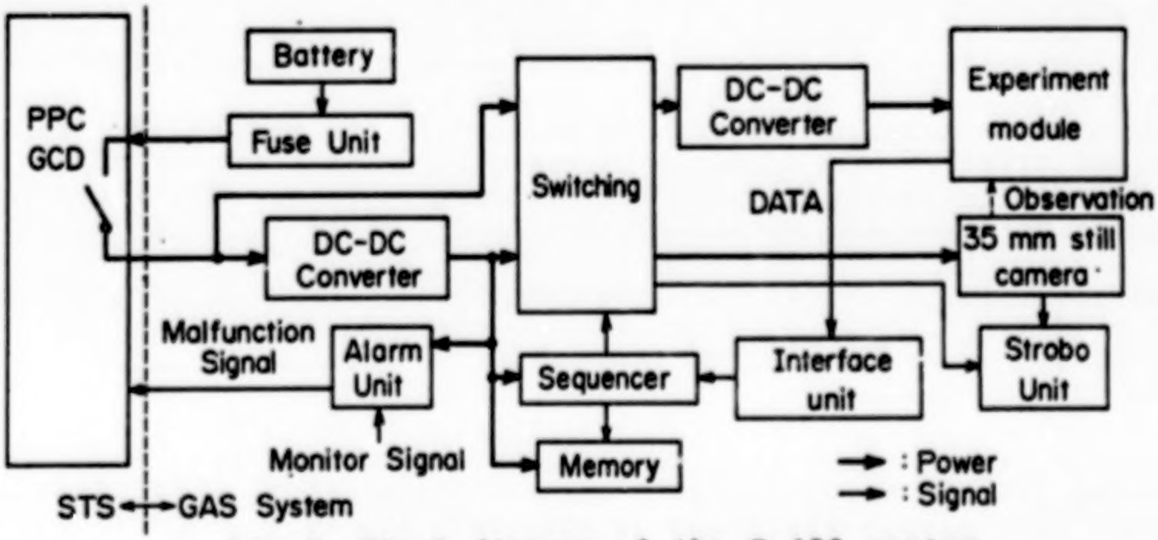

Fig.3 Block diagram of the G-459 system

features are explained below.

1) Subsystems for Experiment Control

For automatic experiment sequencing and for repeating experiments, an 8-bit CMOS microprocessor which consumes little electricity and a PROM are used. The experimental sequence can be changed easily by modifying the program on the PROM.

2) Subsystems for Data Recording

The G-456 and G-457 use a combination of a video camera and video cassette recorders, and the G-458 and G-459 use a 35-mm camera for recording the image data of experiments. The video cameras used have solid-state image sensors and are reliable and environmental resistant. We use two portable video cassette recorders for each system as one for redundancy. All recording equipment have been structurally reinforced.

Power source voltage, container temperature and each subsystem's temperature and voltage supplied to each subsystem are recorded in EEPROMs. In case for G-456 and G-457, they are alse recorded on the audio channel of video tape. If these data exceeds the predefined ranges, an alarm signal will be transmitted to the Shuttle. The system's main switch will be shut off by this signal.

3) Power supply

We selected lead-acid storage batteries made by the Gates Co., for power source. For the G-456 and G-457 systems, the battery assembly has a total capacity of 12.0 V x 50 A-hours (= 600 W-hours) with 24 cells and G-458 and G-459 have 12.0 V x 75 A-hours (= 900 W-hours) with 18 cells. Fuses and diodes are installed for safety measures. Diodes are installed in each series unit of battery cells to prevent current reversals between the battery cells.

DC/DC converters convert and stabilizes the 12-V source power from the batteries and they supply the electricity to each subsystem.

4) Support structure

We used shelves-supported-by-struts structure for our experiment systems (see Fig. 2). This kind of construction is one of recommendations of NASA.

Two discs and four supporting struts are assembled rigidly. All these components are made of aluminum alloy A7075 and A5052. The camera and electronics are mounted on support struts or between struts. Batteries are mounted on the top disc between the lateral supports. The experiment module is mounted on a stand attached to the bottom plate.

Holes for mounting screws are drilled in the supporting struts and in the discs at each constant distance. Position tuning mechanism for the camera is included in its support. These considerations enable standardized use of our systems.

4. Special Considerations for Biotechnological Experiments with GAS

There are many restrictions on the GAS payload. Among them, waiting period for launch of more than two months was most crucial for our systems because delicate biological matters, living organisms and fluids are needed in biotechnological experiments. In such restricted condition, it is difficult to develop a system for carrying out a significant space experiment, especially a biotechnological experiment. Actually, there have been very few

successful biological experiments (Ref. 1). Special considerations are therefore needed as follows.

Thermal control

For our experiment systems, we will use insulated end caps and we have requested the passive thermal control (PTC) mode for the Shuttle flight. In this flight mode, the Shuttle rotates around its X-axis to keep the temperature as constant as possible so temperatures within the GAS container fluctuate between 0 C and 40 C in case that the power consumption within the container is below 30 W (Ref.2). This temperature fluctuation is quite small for space, but is large for experiments whose contents are liquids and biological samples. For example, the liquids cannot be allowed to freeze. Furthermore, if the temperature in the experiment module of G-468 drops below 17 C, the growth of the cellular slime mold is inhibited and if the temperature rises above 27 C, the cellular slime mold is killed. In the G-459, the most efficient temperature for the growth of protein crystals will be room temperature, but this varies with the type of protein used.

Because of battery limitations, we use passive methods for thermal control using heat insulators, heat reservoirs and antifreeze. According to experimental requirements for thermal control, we have carefully selected materials and their compositions for these thermal control methods. It was confirmed by environmental tests that thermal controls of sufficient quality have been achieved for all systems.

Handling of fluids

All systems contain fluids. Leakage, evaporation, and bubble formation must be avoided. Measures must also take the approximately two-month waiting period into consideration. To avoid above problems during this two-mouth period, we have been with great care for materials for sealing, designing containers for liquids and method for sealing. For example water diffuses through acrylic resin containers and silicon rubber packing, so they cannot provide a perfect seal for two month. We therefore used "Viton" packing and a special less permeable resin. We have conducted long-term tests and confirmed their durability for preservation.

Contamination

Protein, slime mold and culture mediums for biological substances are used in all experiments except for the G-456. Therefore, if other bacteria mix with an experiment system, problems of metaplasia and putrefaction will occur during the waiting period. Therefore, containers and transportation tubes that hold these substances are designed so that they can be sterilized. They are also designed so that they can be assembled apart from other mechanical sections.

5. Concluding Remarks

Production of the four biotechnological space exberiment systems for the GAS have been completed (Fig.2). Tests of operation and durability for envirouments such as temperature and vibration were also conducted successfully. We have obtained significant results of ground experiments which will be compared with the result of experiments carried out in space. Some of these results are shown in Fujita et al.(Ref.3). Other than these four systems for biological experiments, we have also developed a GAS system for the crystallization experiment of compound semiconductor materials (GaAs and PbSnTe) which is shown in Ref.4. We hope early launching of our systems soon after the resumption of the Shuttle flight program.

The possibilities for utilization of the space environment are virtually unlimited and many nations have space programs. To encourage major projects, accumulating as much basic data and experiences as possible is of great importance. GAS can easily achieve these goals. Our four experiment systems introduced here are not only significant in biotechnology, but can be adjusted and used for experiments in other fields. We expect these systems will be able to meet future demands to make use of GAS as well as the success of these four experiments.

Acknowledgement

The authors would like to express thier sincere appreciation to the Mechanical Social Systems Foundation who supported the development of experiment systems and also to the Ministry of International Trade and Industry who is promoting this GAS program in Japan.

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GAS EXPERIMENTERS SYMPOSIUM

SEPTEMBER 27-30, 1988

TUBSAT-1, SATELLITE TECHNOLOGY FOR EDUCATIONAL PURPOSES

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Abstract

TUBSAT-1 (Technical University Berlin Satellite) is an experimental low-cost satellite within the NASA GAS (Get Away Special) program.

This project is being financed by the German BMFT (Federal Ministry for Research and Technology, mainly for student education. The dimension and weight are determind by GAS requirement and it will be ejected from the space shuttle into an approx. 300 km circular orbit. It is a sun/star oriented satellite with an additional spin stabilisation mode. The first planned payload is to be used for observing flight paths of migratory birds from northern Europe to southern Africa and back.

Introduction

It was a big challenge for the students to design and develope a low-cost experimental platform which enable a rather precise orientation in orbit. GAS program provides a low-cost with high launch frequencies, so that the students can complete their own experiments in the short study period.

It was leading to the development of the GAS compatible satellite of the Technical University Berlin (Fig. 1). More than 50% of its volume is planned for useful experiments like navigation (white storks) equipment and components for space application (star sensor, GaAS solar cells), store forwards communication (mail-box), observation (CCD-chip camera).

The cooperation with MBB (Messerschmidt Bölkow Blohm) in this project is important in order to provide exchange between space industry and the university. Some of TUBSAT-1 subsystem and ground segment have been tested already using the flight opportunity of MIKROBA (OHB-SYSTEM project, supported by BMFT) in Esrange, Sweden in April 88.

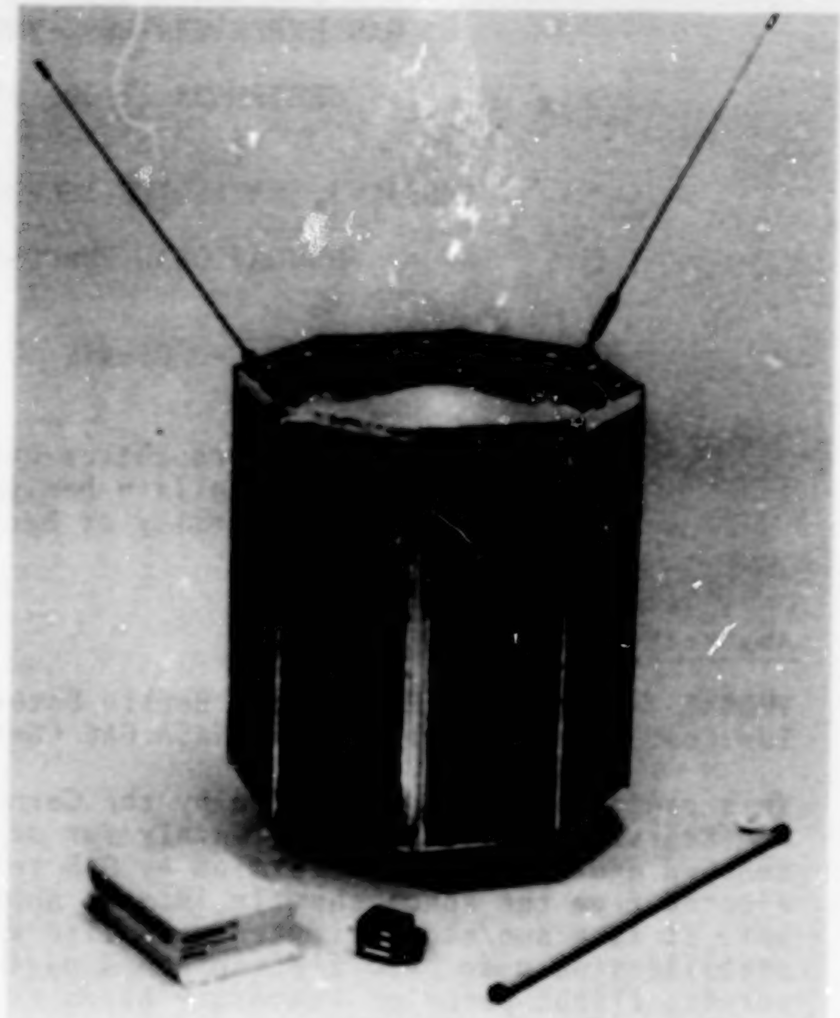

Fig. 1 TUBSAT-1 main component:

- FMW
- OBDH + TM/TC
- star-sensor
- magnetic rod

Mechanical Structure

The mechanical structure of TUBSAT-1 (fig. 7) consists of two major components, a central structure and outer shell.
The central structure is composed of two crosswise mounted sandwich plates, an octagonal shaped sandwich plate mounted at the top, and an adapter ring is placed at the bottom. The central structure provides rigid support to mount all TUBSAT equipment. The adapter ring has been designed for compatibility with the marman plate of the GAS ejection mechanism.

The outer shell is composed of eight panels and eight supporting struts. The panels provide support for the solar array. The struts interconnect the solar panel to the central structure, so that the outer shell can be easily dismounted from the central structure to ensure accessibility to all components.

The main parts of the structure are considered in strength verification analysis, using a detailed finite element model to calculate accurate forces and stresses with respect to the GAS payload safety requirements. It is to state that all parts are covered with positive margin of safety.

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Mass distribution:

- structure and interface ring	5.33 kg
- solar panel	4.02 kg
- fixed momentum wheel	7.60 kg
- batteries	3.84 kg
- electronics	3.21 kg
- TM/TC + OBDH	2.00 kg
- torque rods	6.00 kg
- payload	36.00 kg
total	68.00 kg

On bord data handling subsystem (OBDH)

The on bord data handling subsystem (Fig. 2) manages and coordinates all subsystem and experiments. It is based on Hitachi (HD 63701 XO) 8 bit CMOS single chip microcomputer unit (IC1) which contains 4k bytes of EPROM and 192 bytes of RAM. If excess information is to be stored, the included external 32 k bytes RAM (IC3) can be used. It also contains an analogue/digital converter (IC2) with 16 analogue inputs. The buffer (IC4) is used for the interface to the TM/TC subsystem. Additional serial interface are provided for the attitude control subsystem and for three different experiments. They all should have their own microcomputer to enable efficient communication. The "watch-dog-timer" (IC5,6) listens carefully every 65 ms to the heart pulse of the computer, in case of a heart attack (no pulse after 100 ms) shock therapy follows immediatly through resetting.

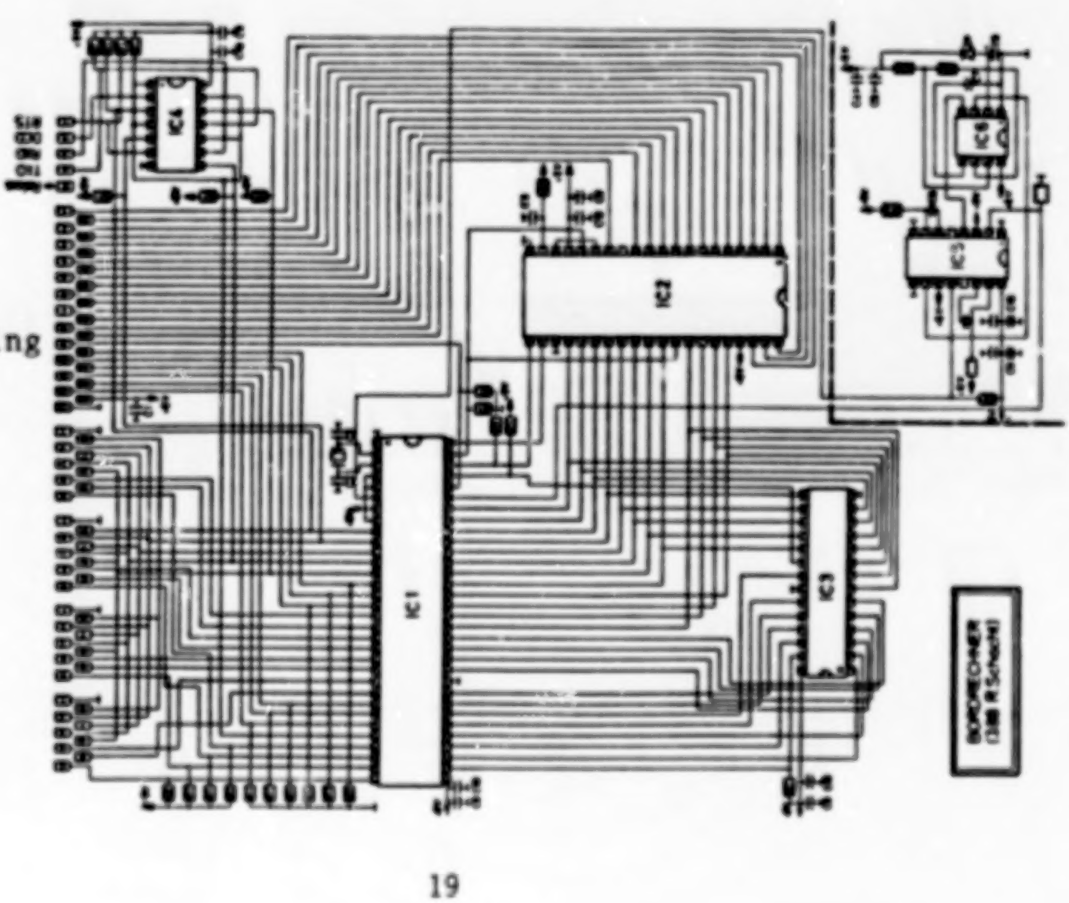


Fig. 2
On bord data handing subsystem

Thermal analysis

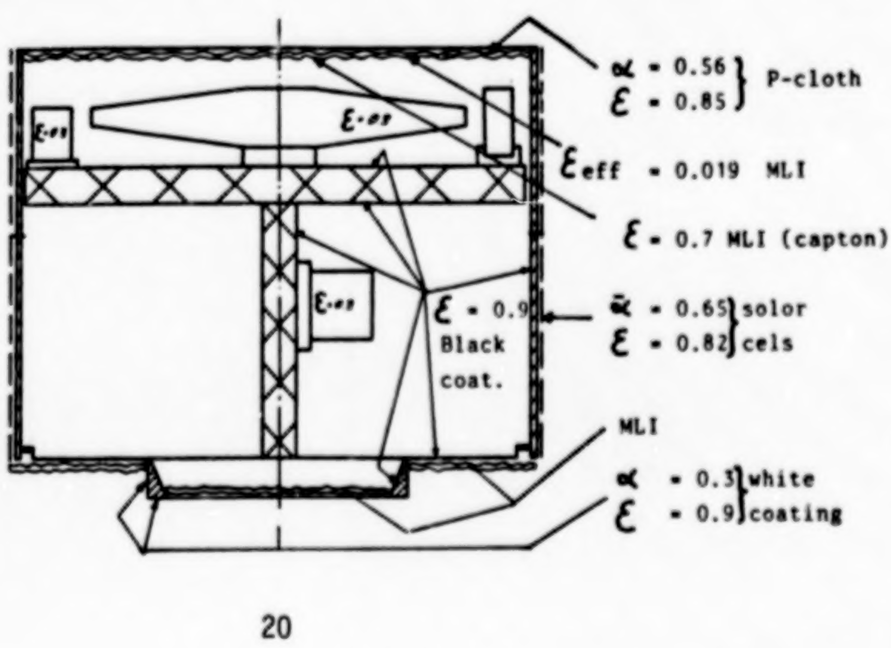
The successful operation of the battery, electronic equipment and payloads, requires a fairly close control of the temperature to which it is subjected. Even though it is a disadvantage from a thermal point of view to spread out the batteries around the momentum wheel, it has been done mainly for space optimisation reasons.
For the transient orbital temperature analysis, the TUBSAT orbit data have been assumed, taking into consideration the albedo, solar and earth source of radiation, and the dissipation power of the satellite equipment. One node model has been developed, it consists of 59 nodes with different heat rate input according to the three attitude modes.

A: 3-axes stabilised (solar panel edge pointed to the sun)
B: " " " " surface " " " "
C: spin stabilised

By using multilayer insulation (MLI) on the top and bottom of the structure, black painted equipment on the inside area, and white painted outside surfaces (Fig. 3).
100 orbit cycles were repeated in order to obtain an exactly permanent periodic state. In all three calculated attitude modes, the analysis has shown a possible operating temperature range as follows.

temp. °C/	battery		electronics		solararray	
mode	min	max	min	max	min	max
A	11	32	3	36	-33	64
B	9	31	0	28,5	-35	67
C	16,7	13,6	5	25	-24	32

Fig. 3
Radiative properties in the node model



Power Subsystem

From examination of the mission profils, it is apperent that the solar generated power has a wide voltage variation, therefore it is necessary to provide good battery management to control and optimize the charge function of the battery. A maximum number of 49 solar cells of the type k7000 Spectrolabe (62.1x20.9 mm) can be attached to each of the eight panel. Matching process of all 392 cells have been done, considering the working point voltage of 23.5 V for each solar panel. This value is based on the maximum charge voltage available of the chosen batteries. So that each panel supplies an average current of 535 mA, almost the same power (12.65 W at 28° C) and 32 W (28° C) when light striks perpendicular to the pitch axis.

In the spin mode according to the thermal analysis the average temperatur of the arrays is less than 28° C so that a power increase is expected. In the 3-axes mode, a power drop of 40% from the panel facing the sun (60° C array temperature) is expected.

The battery system consists of a string of 16 Nickel-Cadmium cells each 7Ah, 1.47 V (VR7 SAFT). Assuming a 90 minute orbit with a 38 minute exlips time, a power supply of 32 W, with 75% of battery efficiency it would yield 17 W (23.5 V/0.72 A) available power consumption. This means, that the 15 W battery required charge power (charge rate of 0.1 C = 0.7 A), is in the safety margin. The 3-axes mode electronic includes step-up converter for each panel to increase the supply voltage to the proper charge value.

In the spin mode the shunt regulator uses a cell temperature signal to avoid battery overcharge, or "allowing" colder cells a full charge (Fig. 4).

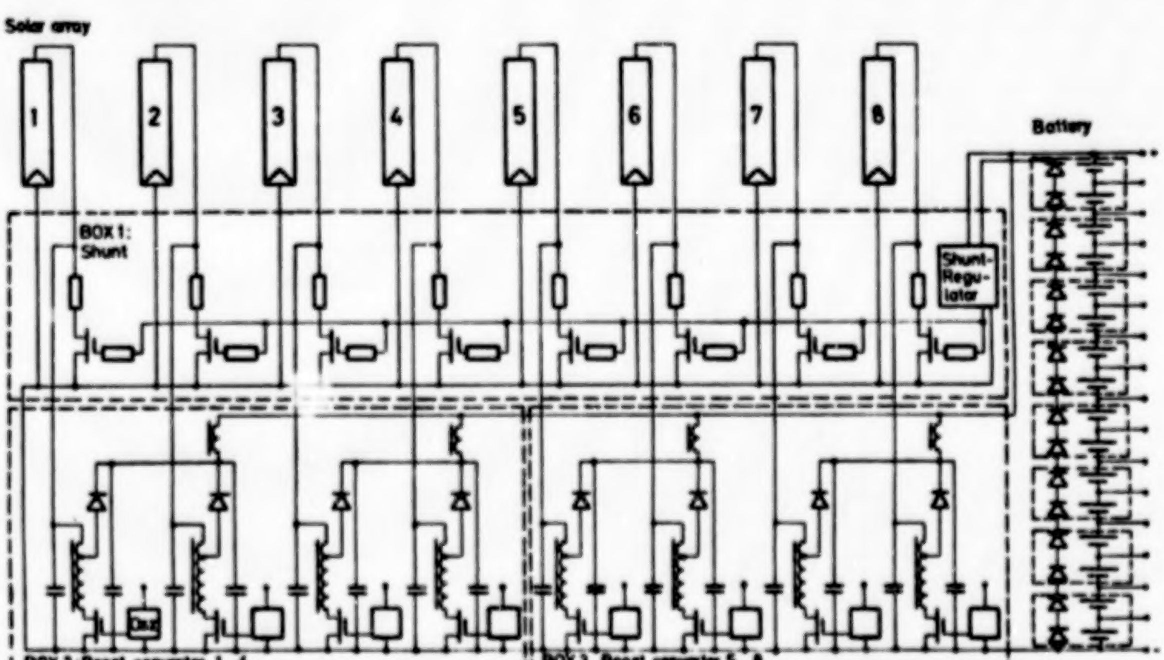


Fig. 4 Power subsystem

Attitude control and stabilisation subsystem

The attitude control and stabilisation subsystem (ACS) consists of a fixed momentum wheel (FMW,50nms,Teldix), magnetic rods, sun-, star- and geomagnetic field sensors (Fig. 6).
Two attitude modes are designed, spin and 3-axes stabilisation at momentum vector perpendicular to the sun. The additional possibilities of pointing this vector in any other direction will be tested later on. The ACS concept based on microcomputer unit (MCU) with additional A/D and D/A converters in order to collect and distribute signals for maintaining the required position with respect to any error signal. The star sensor has two working modes, differenciation mode, where every picture is compared to the previous one, and integration mode, where each new picture is being compared to the first one only.
The magnetic rods are used for dump nutation, wheel desatoration and presessing the momentum vector.
Here it is important to mention that the FMW used for the attitude stabilisation should be run up shortly before the satellite will be ejected. This matter has already been discussed in October 1986 with the GAS payload officer.

Telemetry and telecommand subsystem (TM/TC)

Using commercial components with minimum power consumption were the main requirements for design and development of the modem (modulator/demodulator, Fig. 5) and transverter. FM modulation has been chosen, with a bit rate of 400 baud. This value can be changed easily on demand through replacing only 2 resistors (increasing the bandwidth of the appropriate filters). To achieve a compact system, the request to send signals (RTS) is used to change the switch position (receive/transmit), so that the essential part of the system works for transmitting and receiving too. The receiving signal (29 MHz) is being mixed twice to 455 KHz (IC1,2). Variable control oszillator (VCD) compensates the Doppler effect and possible shifting of the other oszillators. The subcarrier frequencies are at 1300/2100 Hz.

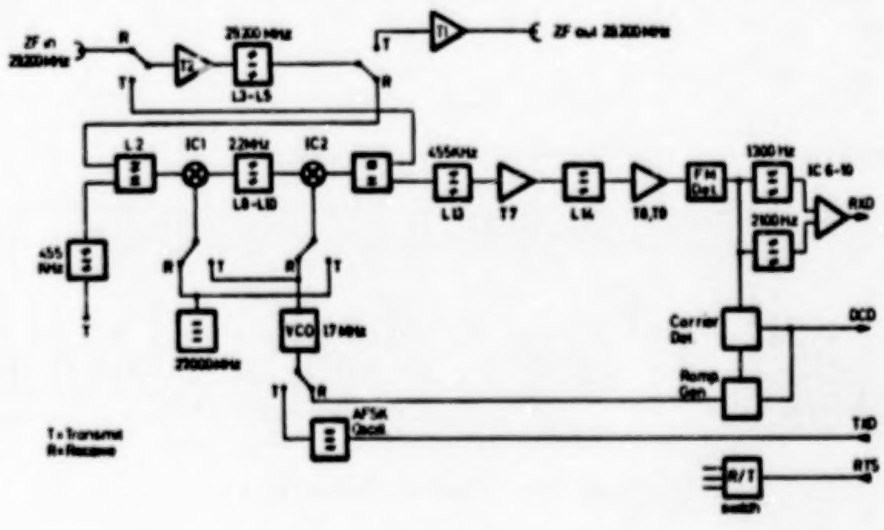


Fig. 5
Modem

2m - 10m transverter mixes and amplifies the modem output signal to the current TM frequencies of 137.8 MHz, 0.1 W power, and vice versa when receiving the 148.1 MHz uplink signal.

Ground station

With orbit inclination of 57° TUBSAT-1 will be controlled by the main ground station, which is placed at the Technical University of Berlin, in case of lower orbit inclination, the already existing portable ground station can be placed anywhere in the mediterranien countries to enable contact.

All ground stations are similar and use the same communication terminals as on board, with only different extensions.

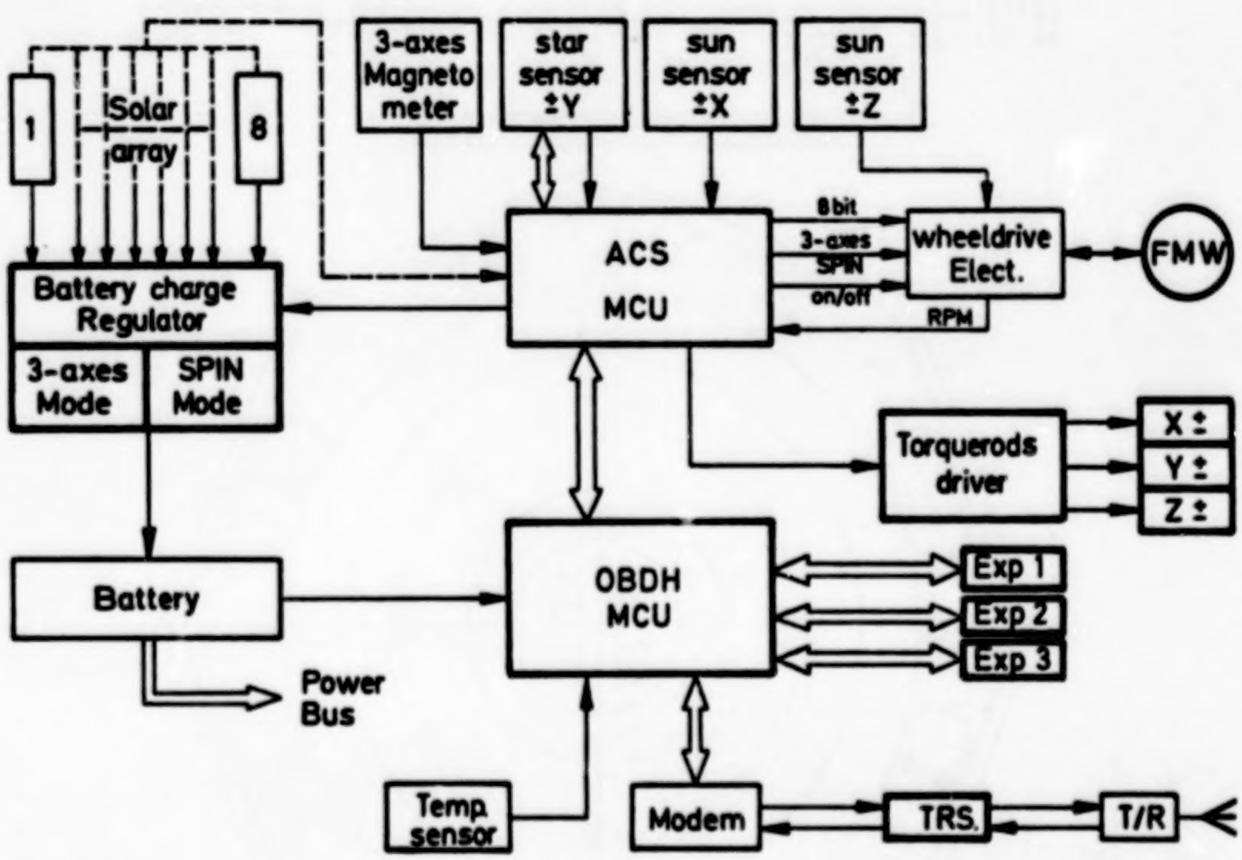


Fig. 6 TUBSAT-system diagram

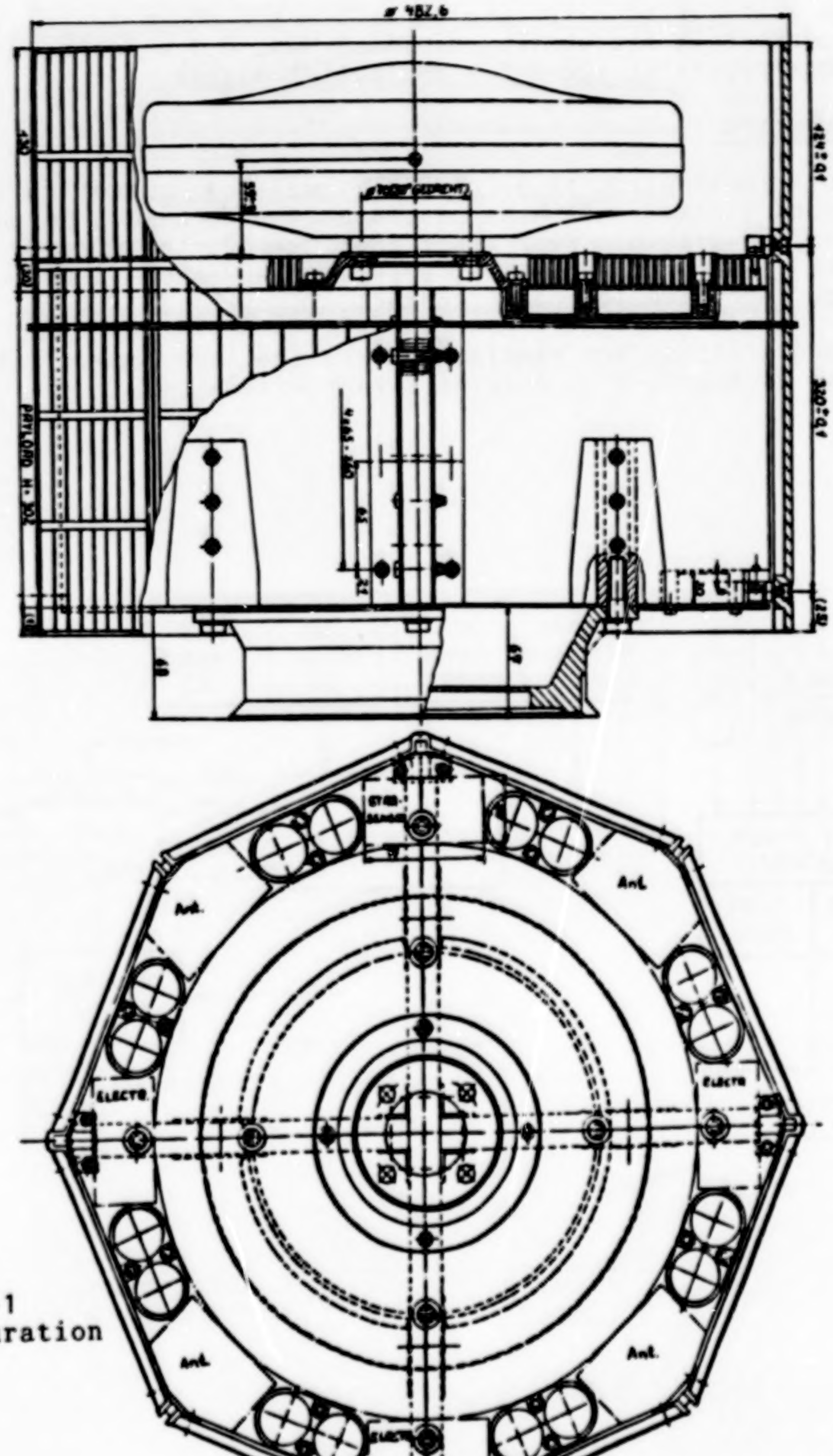


Fig. 7
TUBSAT-1
configuration

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FUTURE MAUS PAYLOAD AND THE TWIN-MAUS CONFIGURATION

Abstract

The German MAUS project was initiated in 1979 for optimum utilization of NASA's Get-Away-Special (GAS) program. The MAUS standard system has been developed to meet the NASA requirements for flying in Get-Away-Special containers. MAUS can accommodate a wide variety of GAS-type experiments, and offers a range of services to experimenters within a framework of standardized interfaces.

Currently, four MAUS payloads are being prepared for future Space Shuttle flight opportunities, and are described in this paper. The experiments include critical Marangoni convection, oscillatory Marangoni convection, pool boiling, and gas bubbles in glass melts. Two of them are reflights with modified scientific objectives, and the other two are new experiments. Scientific objectives as well as experiment hardware will be presented together with recent improvements to the MAUS standard system, e.g. new experiment control and data management unit and a semiconductor memory.

A promising means of increasing resources in the field of GAS-experiments is the interconnection of GAS containers. This important feature to meet the challenge of future advanced payloads has recently been studied. In the TWIN-MAUS configuration, electrical power and data will be transferred between two containers mounted adjacent to each other.

1. Scientific Objectives

The experiments in preparation are from the area of materials science and the results will improve the understanding of selected basic microgravity phenomena (Ref. 1).

The complex features of Marangoni convection will be further elucidated by two separate experiments. The objectives are as follows: documentation of the influence of iso-rotation on the steady and oscillatory state of convection, evaluation of the shape stability of the floating zone configuration during rotation, determination of the influence of higher Marangoni numbers on the hydrodynamic stability by variation of the temperature gradient. Convection is made visible in silicone oil by dispersed Al_2O_3 particles.

In a reflight of a previous successful MAUS experiment the onset of oscillatory Marangoni convection in sodium nitrate is further investigated. The frequency spectrum at higher Marangoni numbers with different aspect ratio will be measured and analysed to describe the transition to turbulence. In ground-based and flight experiments the Prandtl number, the aspect ratio and the gravity influence are varied systematically.

Pool Boiling (nucleate boiling) and forced convection are the most effective heat transfer mechanisms. From the many fluid physics phenomena which are observed in boiling, kinetic heat and mass transport by evaporation and condensation is independent of gravity. This experiment will lead to a physical separation of the gravity driven parameters and trence to a better understanding of the boiling process.

Fining is one of the most important processes in technical glass fabrication. The removal of gas bubbles from glass melts can be achieved in two ways: rising of the bubbles caused by buoyancy (which does not occur in microgravity) and dissolution diffusion. The shrinking of a He-bubble at around 1100°C was successfully recorded in a previous MAUS experiment. This investigation will be performed at the higher temperature of 1300°C to complement data on the diffusion in a wider temperature range. The convectional influence is expected to be stronger, and a larger difference between terrestial and space experiments because of reduced viscosity will result.

2. Experiment Hardware

In MAUS experiment DG 302 thermal Marangoni convection in a floating zone is initiated by an axial temperature gradient along a free surface.

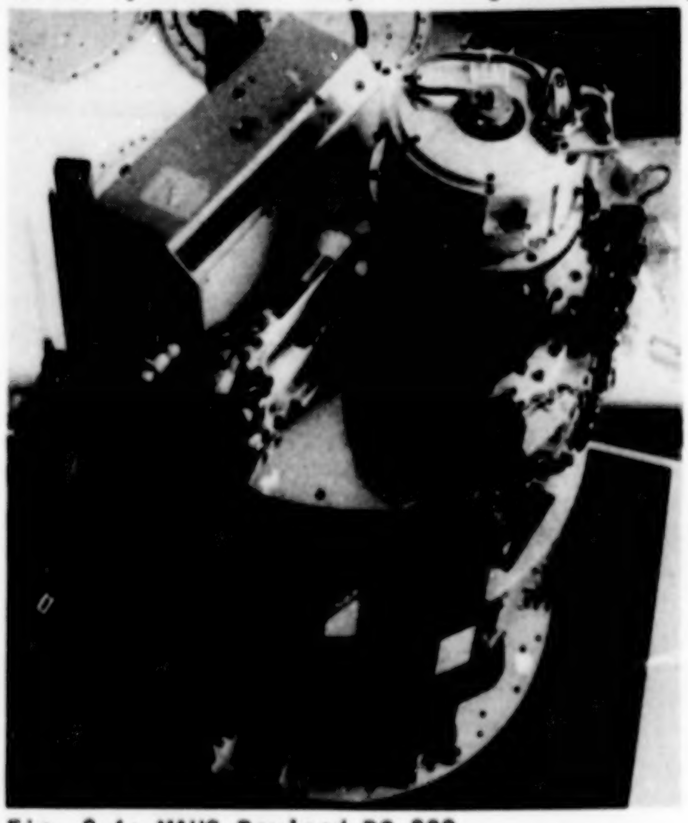

Fig. 2-1: MAUS-Payload DG 302

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A cylindrical floating zone is formed between two coaxial discs which can individually be rotated by two electric motors. The discs are in contact with each other before the silicone oil is injected by retracting one of the discs. The test liquid enters into the gap between the two discs through a central hole in the the retracting disc. At any axial location, sufficient test liquid is injected to form a cylindrical floating zone.

Convection is made visible by small particles dispersed in the silicone oil. An optical plane generated by a He-Ne Laser assembly illuminates the particles on the meridian plane of the floating zone. This "light-section" technique enables motion pictures of two dimensional velocity components to be taken. The resulting film will show the onset of the Marangoni convection phenomenon, and the mass transport effects which it causes.

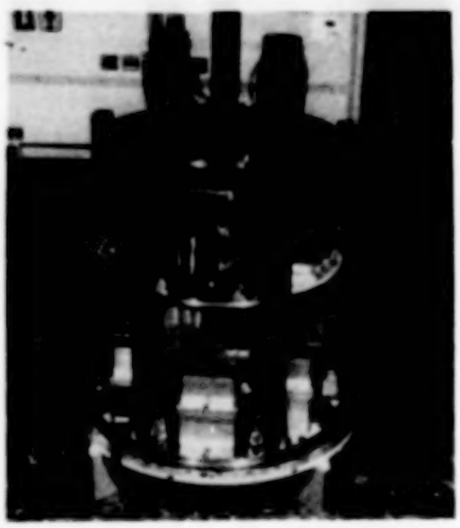

Fig. 2-2: MAUS-Payload DG 321

In MAUS experiment DG 321 two experiment chambers with zones of different length are mounted on the upper experiment platform and operated simultaneously . The floating zone is established by melting a solid $NaNO_3$-cylinder between two graphite pistons. The liquid zone is held in position by surface tension forces. The graphite pistons are screwed into resistance heaters mounted in the housing of the hermetically sealed experiment chambers.

Thermocouples are used to control the temperatures of the heaters and of the pistons. A second thermocouple records the temperature oscillations in the liquid zone. The signals of the thermocouples as well as the heater currents are fed to the MAUS data acquisition system.

MAUS-Payload DG 504 has been described in detail during the 1987 GAS Symposium, (Ref. 2) therefore only the experiment cell is presented here.

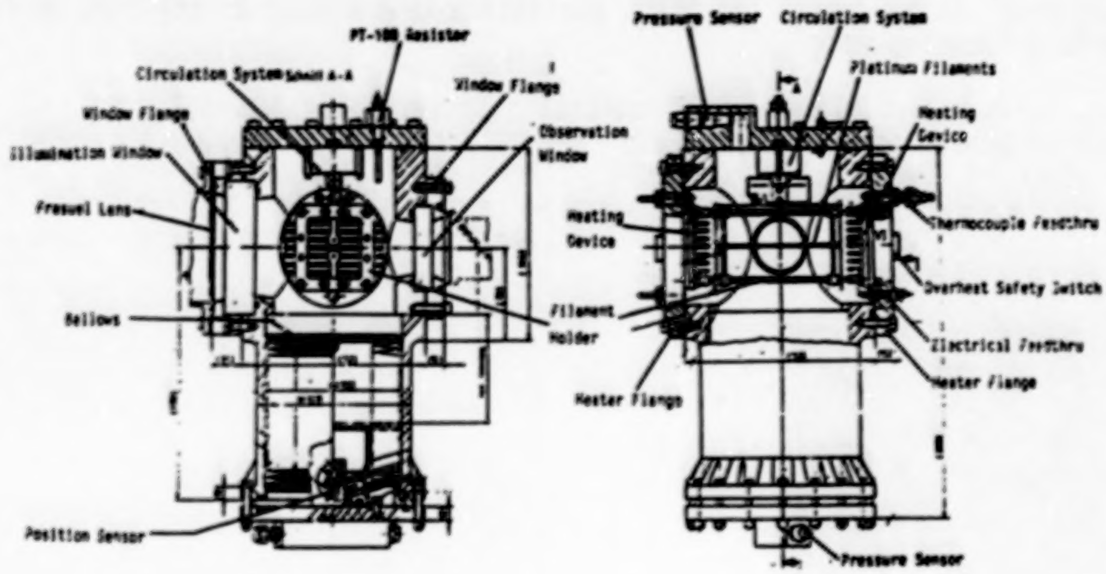

Fig. 2-3: Experiment Cell DG 504

A test liquid Freon R12 is contained in the experiment cell the basic geometry of which is a cube, having three cylindrical hollow spaces perpendicular to each other. Each of them is closed by two opposite flanges. A cylindrical extension contains a bellows which can be filled with nitrogen gas to achieve the desired pressure values. Windows on opposite sides of the cube allow for illumination and optical observation. Two heating devices are installed on the inside of the remaining two opposite flanges. Additionally, the liquid can also be circulated by a rotating paddle mounted on the upper flange. Two platinum filaments are mounted on an exchangeable filament holder. Eight thermocouples provide for temperature monitoring capability at different locations within the experiment cell. The Freon temperature is measured and controlled by a PT-100 sensor. The pressure of the nitrogen gas and of the Freon will both be monitored and controlled by piezoresistive absolute pressure transducers. To prevent overheating an overheat safety switch is mounted in good thermal contact on each of the heater flanges.

Other subsystems needed to operate this payload are the Freon expansion container, the pressure system, the optical system, and the interface electronics.

MAUS experiment DG 324 will be carried out to expand the data of experiment DG 318, successfully performed on STS-11. The same experiment configuration will be used, but with a different experiment profile (higher temperature, longer duration). The cylindrical glass sample (74 SiO_2 16 CaO - 10 Na_2O) with an artifical helium bubble at its center is held by a platinum tube which is closed by transparent sapphire windows. The furnace has an opening at either end, one for illuminating the bubble by a flashlight and the other for taking photographs.

The temperature of the sample will reach 1300°C during operation. A thermal analysis showed that only the integration of heatpipes can provide the needed heat flux to achieve a reasonable temperature distribution within the container.

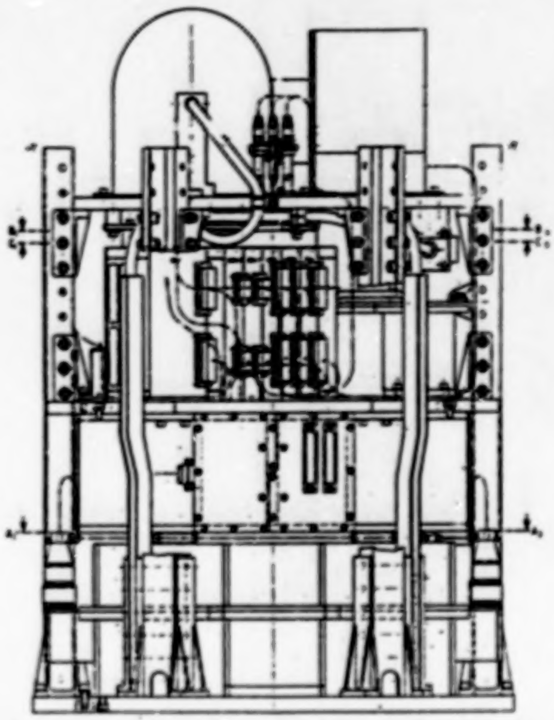

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Fig. 2-4: MAUS-Payload DG 324 with Heatpipes

Three heat pipes are directly coupled to the upper experiment platform on which the furnace is mounted. The opposite ends of the heatpipes are screwed to the brackets which connect the posts to the adapter ring. These modified brackets provide a larger contact area to the heatpipes as well as to the adapter ring, and assure adequate thermal conductance to the GAS container top plate, from which the heat will be radiated to space.

3. Improvements to the MAUS Standard System

The hitherto existing standard electronics for experiment control and data acquisition were developed almost ten years ago, but are now out-of-date and no longer suit the requirements of the experimenters, especially considering data resolution (10 bit) and data evaluation (Ref. 3). Four units of a new experiment control and data management system, based on an existing MBB-ERNO design, will be available to the MAUS project this year. To avoid changes in the existing experiment accommodation the modules will be housed in the existing casing. In its basic configuration the system will only consist of three modules, two for experiment control and data acquisition, and one for data storage. Additionally, a dc/dc converter replacing the electronic batteries will be included in the housing.

Fig. 3-1: Modules for Experiment Control, Data Management and Storage

Among other features this system allows for higher resolution (12 bit), higher data acquisition rates and easy data evaluation. Due to standard interfaces a PC can be used as EGSE. Data storage will be performed by a semiconductor memory with a basic storage capacity of 10 Mbit. This capacity can easily be expanded in steps of 20 Mbit. Also the number of digital and analog I/D's can be increased or adapted to the needs of a particular experiment. Generally, this new system is much more flexible in use.

4. TWIN-MAUS Configuration

A concept for the extension of MAUS payload resource limits has recently been analysed in the TWIN-MAUS (Two-Interconnected MAUS-Payloads) study. Generally in the existing MAUS system the resources are limited with respect to energy, volume/mass, experiment duration, heat dissipation, and data storage capacity.

The currently developed EURECA experiment HPT (High-Precision-Thermostat) has been chosen as a model payload because it is a rather complex experiment accommodated in a GAS canister with a modified MAUS experiment mounting structure and a modified end plate being used as a radiator. The HPT is an almost autonomous facility providing its own experiment control and data acquisition system. Fluid physics experiments can be carried out within precisely defined temperature ranges.

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The resource requirements of the model payload for a typical five day mission have been compared to resources offered by the MAUS system. The energy needed is about 10 kWh and approximately 100 Mbit of data will be generated, both depending on the actual experiment. The facility occupies the whole volume of a standard 5ft. GAS-canister.

To operate an experiment with resource requirements like the HPT, the GAS program offers the possibility of interconnection of GAS-canisters. An appropriate concept has been defined and analysed.

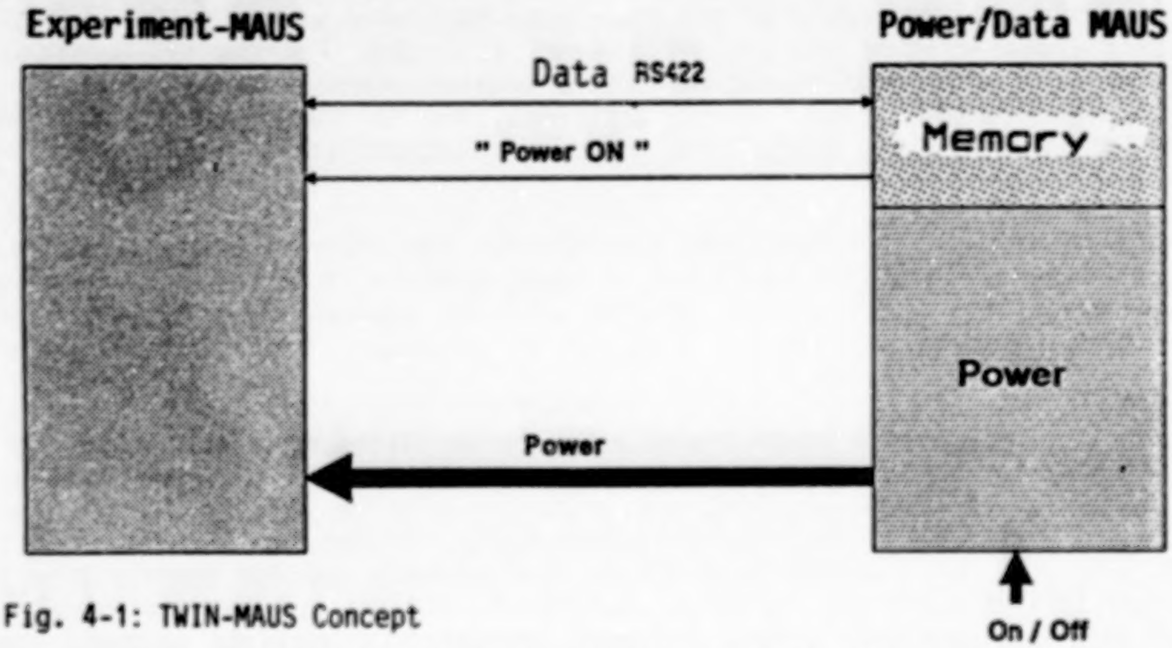

Fig. 4-1: TWIN-MAUS Concept

One canister contains just the experiment, in this case the HPT with its own experiment control and data acquisition unit. In the other containner, the needed batteries, a power distribution unit, and a data memory unit are accommodated. All electronics are compatible with or even identical to the new MAUS electronics.

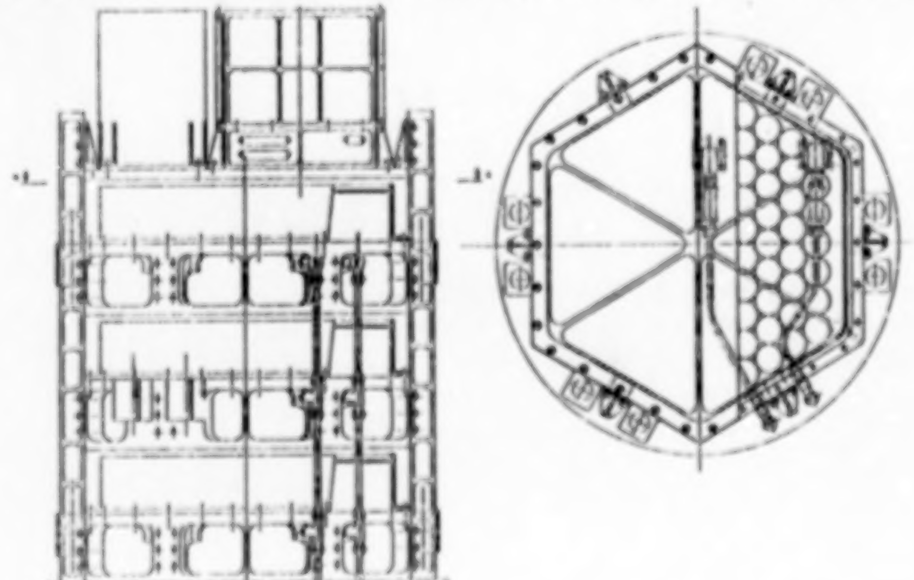

Fig. 4.2 Power/Data MAUS Design

The structural design of the Power/Data-MAUS is completely different from the existing MAUS hardware. Due to the limits of mass and load capacity the experiment mounting structure as well as the battery housing can no longer be used. A new self supporting battery housing has been designed. Up to three can be assembled in the Power/Data-MAUS by means of triangular shaped posts. Each of the batteries can be equipped with 180 Li SO_2 cells producing a total energy of 10.5 kWh. The two electronic units are mounted on a platform above the batteries.

A thermal analysis has been performed considering the TWIN-MAUS configu ration. It turned out that all components of the Power/Data-MAUS were within their temperature limits independent of the orbiter thermal attitudes. For the HPT having a power dissipation of 90 W it turned out that a passive thermal control concept is only possible by avoiding hot thermal attitudes. Due to the necessary emission characteristics of the top plate deep space orientations (cold case)have to be limited to 7 hours.

As a rough reference value for other experiments, the thermal analysis showed, that with a maximal power consumption of approximately 75 watts a continuous operation during the whole shuttle mission will be possible. But to get more precise values a detailed thermal analysis is necessary for each particular payload.

As a further aspect of the study the possibility of flying experiments like the HPT in GAS-canisters on the carriers Hitchhiker-G, -M, and DOM (a German payload carrier system), was examined. Only one container will be used in that configuration, the resources of the Power/Data-MAUS being provided by the carriers. All carriers offer up- and downlink capabilities, additionally the DOM carrier offers active cooling by a Freon cooling loop. Looking at cost and availability aspects, the TWIN-MAUS configuration offers the most promising possibility to meet the challenge of future advanced payloads.

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Development of Experimental Systems for Material Sciences Under Microgravity

Jun Tanii*, Shinzo Obi*, Yotsuo Kamimiyata* and Akio Ajimine**

Abstract

Three experimental systems --G452, G453, G454-- have been developed for material science studies under microgravity by the NEC Corporation, as part of the Space Experiment Program of the Society of Japanese Aerospace Companies. These systems are to be flown as Get-Away Special payload for studying the feasibility of producing new materials.

The three systems all comprise standard subsystems consisting of : -

- Power supply
- Sequence controller
- Temperature controller
- Recorder (data recorder of VCR)
- Video camera,

together with the experimental modules carrying the hardware specific to the experiment.

1. Introduction

The Get-Away Special (GAS) Program has been offered by NASA to a number of countries including Japan, providing the opportunity to purchase payload space onboard shuttle flights. Japan has already had two experiments flown : -

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- G-005 for producing artifical snow[1], and
- G-032 for an experiment on the collision between small balls of metal and of water[2].

These payloads were developed by NEC under contract with the Asahi Shimbun and the Asahi Broadcasting Company. The Society of Japanese Aerospace Companies and NEC have utilized the experience gained in the development and manufacture of the foregoing two systems to further develop system for studying the feasibility of producing new materials under conditions of microgravity.

The most difficult problems calling for solution in development were to install the maximum possible number experiment modules within the prescribed limitations of space mass, which called for devising a miniaturized furnace for sample melting with minimum power consumption, to reduce the required number of batteries.

2. Overview of Experimental Systems

The principal characteristics and features of the three experimental systems are as summarized in Table 1. The hardware presents the external appearance shown in Figure 1.

The payload support structure is cantilevered out from the Experiment Mounting Plate (EMP), and supported laterally by 4 stoppers arranged on the two sides opposite each other.

As presented schematically in Figure 2, each system consists of an experiment module carrying the hardware specific to the experiment and a standard subsystem --of composition common to all three systems-- comprising 5 electrical circuit units for : -

- Sequence Control (SCU)
- Temperature Control (TCU)
- Power Conditioning
- Alarm
- Interface,

together with auxiliary components convering : -

- Battery assembly
- Transistor power switch unit
- Recording unit.

The SCU controls the ON/OFF status of all the other units

(Recording, Temperature Control, Experiment Module, ...). While the standard subsystem is thus common in form to all three systems, their substance --mode of control-- varies with the experiments, and to accommodate the variants, a high degree of flexibility has been incorporated in the subsystem, with micro-CPU and its peripherals including ROM --schematized in Figure 3-- adapted to the particular experiments. This flexibility will permit accommodation of alterations in the experimental control scenario by simple replacement of the ROM, even at a fairly late phase of experimental system development.

The Standard Recording Unit stores data from the experiment module (material temperature, heater current and other experimental measurements) as well as from the housekeeping subsystem (ambient temperature, battery voltage, ...). In some runs, in-situ images of crystal growth and other physical phenomena require recording, in which case the data recorder is replaced by a CCD color video camera and video cassette recorder: The monitor signals --e.g. material sample temperature-- are recorded on the audio track of the video tape, and image data on the video track. The video camera presents the external aspect illustrated in Figure 4.

3. Experiment Modules

The 12 experiments listed in Table 2 have been selected by a board of Japanese authorities interested in material science and space technology. Some of the modules have been developed by the experimenters, and others by the present authors.

Representative examples of the experiment modules are shown in Figures 5 to 8. Figure 5 and 6 indicate the arrangement of the miniature furnace or ampoule and material samples devised to satisfy the prescribed limitations of space and mass. These furnaces are embedded in thermal insulator, in the manner shown in Figure 9.

4. Concluding Remarks

The three experimental systems described above have been tested in simulated launch and orbit conditions, and have proved to function as expected. Using these systems, experiments have been successfully conducted for acquiring basic data on ground.

The systems thus developed are destined to be flown on the Space Shuttle in the near future, at which time acquisition can be expected of useful material science data under micro-gravitational condition.

5. Acknowledgments

The authors express their sincere appreciation of the kind cooperation and incessant encouragement accorded to the present study by officials and engineers of the NASA Get Away Special Program. Further acknowledgment is due also to experimenters of The Society of Japanese Aerospace Companies --in Hitachi Ltd., in Fujitsu Corporation, as well in NEC-- for their collaboration. The authors are deeply indebted to the Mechanical Social Systems Foundation under the aegis of the Ministry of International Trade and Industry, for the support accorded to the study as part of the Ministry's plan for promoting the GAS Program in Japan.

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TABLE 1 MAIN CHARACTERISTICS AND FEATURES OF EXPERIMENTAL SYSTEMS

	G-452	G-453	G-454
SIZE DIAMETER HEIGHT	50 cm 70 cm	50 cm 70 cm	50 cm 70 cm
WEIGHT	70 kg	80 kg	70 kg
OBSERVATION/ RECORDER	DATA RECORDER	CCD COLOR VIDEO CAMERA VCR	CCD COLOR VIDEO CAMERA VCR
CONTROL	MICRO-CPU, ROM	MICRO-CPU, ROM	MICRO-CPU, ROM
EXPERIMENTS	SEMICONDUCTOR(4)	SEMICONDUCTOR (2) SUPERCONDUCTOR(1) BOILING PHENOMENA (1)	SEMICONDUCTOR (2) SUPERCONDUCTOR(1) FERROMAGNETIC MATERIAL (1)

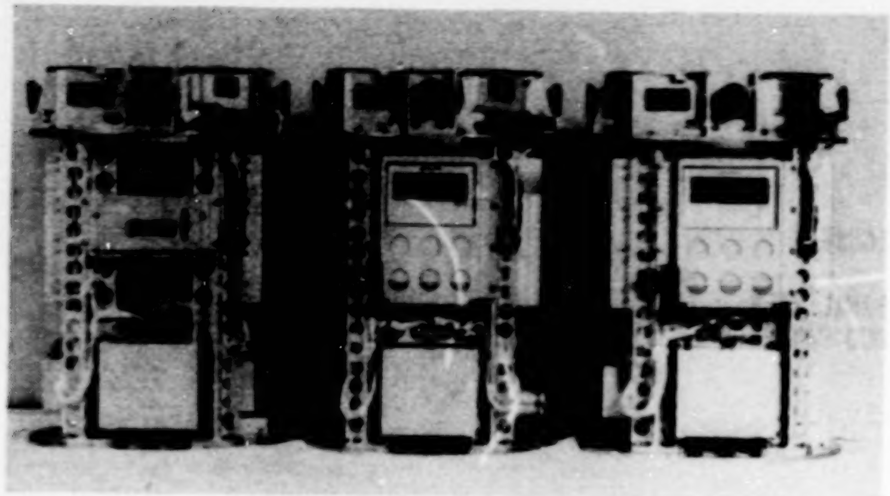

Figure 1 External view of three Experimental Systems

FIGURE 2

STANDARD BLOCK DIAGRAM OF EXPERIMENTAL SYSTEM

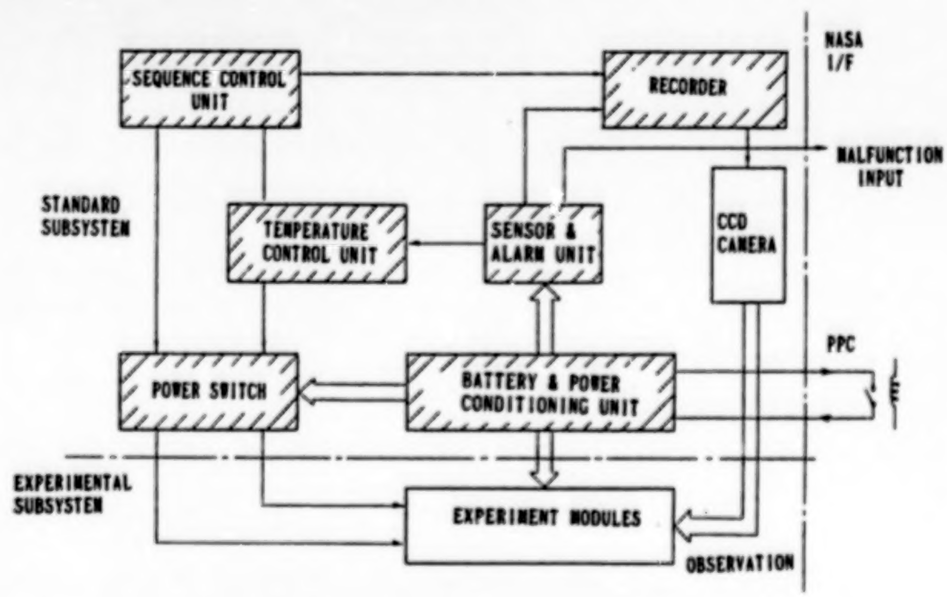

FIGURE 3

SCHEMATIC DIAGRAM OF CPU

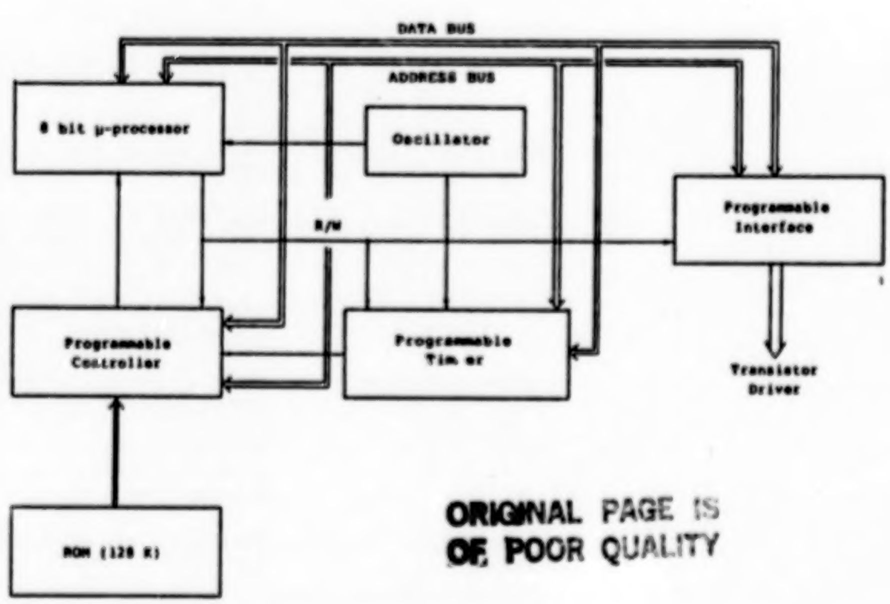

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FIGURE 4

EXTERNAL VIEW
OF CCD CAMERA

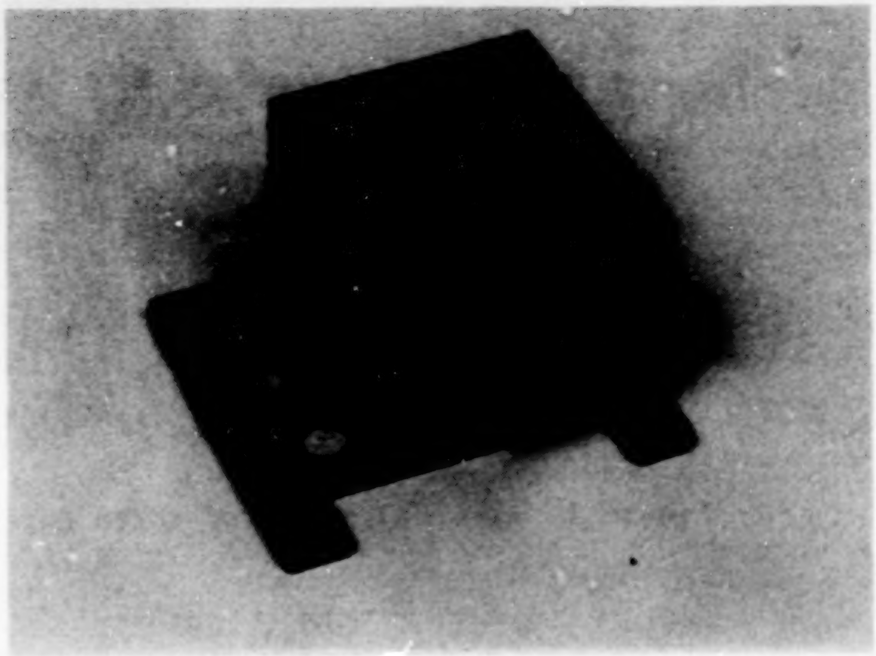

Table 2   Themes of 12 experiments for material sciences

System	No.	Experiment	Theme
G452	1	Semiconductor	Single crystal growth of GaAs from liquid phase (900 c)
	2	Semiconductor	Crystal growth of GaAs based mixed crystal (GaAsSb) (900 c)
	3	Semiconductor	Addition of a heavy element (Bi) to GaAs crystal (900 c)
	4	Semiconductor	Addition of a heavy element (Bi) to InSb crystal (650 c)
G453	6	Semiconductor	Formation of heterogeneous-alloy system from GaAs and Ge (900 c)
	7	semiconductor	Formation of thin-film-type single crystal of compound semiconductor (InSb)
	9	Superconductor	Formation of Si-Pb Alloy (immiscible on the ground) (1450 c)
	12	Boiling	Observation of the bubble form when an organic solvents is boiling under -g. (40 c)
G454	5	Semiconductor	Crystal Growth of In GaAs from vapor phase (800 c)
	8	Superconductor	Crystal growth of NbSe3 from vapor phase (800 c)
	10	Optoelectronic crystal	Crystal growth of an optoelectronic crystal (KH2PO4) by diffusion method (900 c)
	[illegible]	Superferromagnetic alloy	Formation of superferromagnetic alloy (Nd-Fe-B) (1400 c)

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OF POOR QUALITY

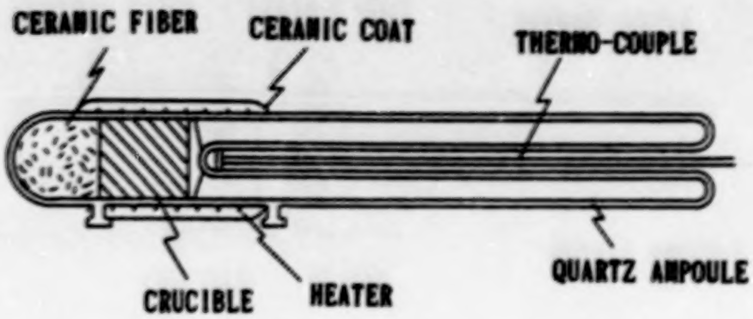

FIGURE 5 SMALL ELECTRIC FURNACES FOR EXPERIMENTS : Nos. 1,2,3,.9,11

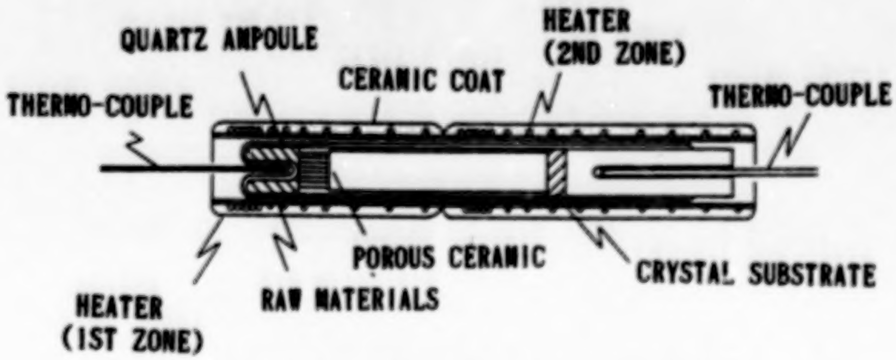

FIGURE 6 SMALL TEMPERATURE GRADIENT FURNACE
FOR EXPERIMENTS : Nos.5 AND 10

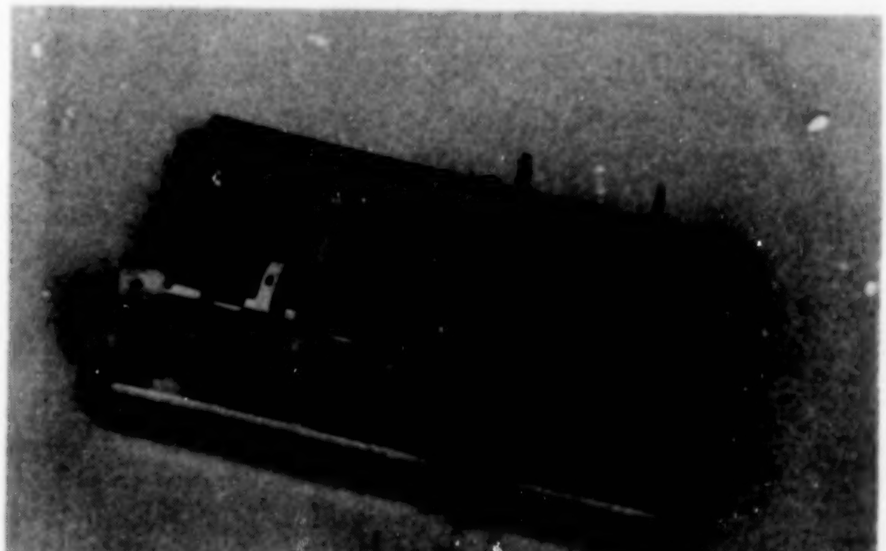

FIGURE 7 EXTERNAL VIEW OF EXPERIMENT No. 8 MODULE

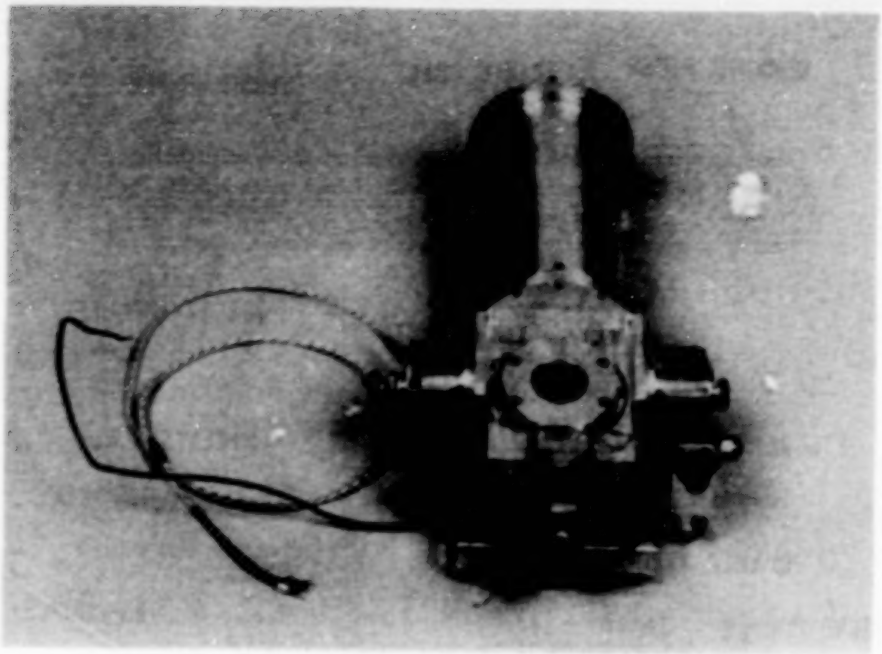

FIGURE 8 EXTERNAL VIEW OF EXPERIMENT No. 12 MODULE

FIGURE 9 SMALL FURNACES EMBEDDED IN THERMAL INSULATOR

N89-10908

HIEN-LO - AN EXPERIMENT FOR CHARGE DETERMINATION OF COSMIC RAYS OF INTERPLANETARY AND SOLAR ORIGIN

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Abstract

The experiment is designed to measure the Heavy Ion Environment at Low Altitude (HIEN-LO) in the energy range 0.3 - 100 MeV/nucleon. In order to cover this wide energy range a complement of 3 sensors is used. A large area ion drift chamber (Sensor 1) and a time-of-flight telescope (Sensor 2) are used to determine the mass and energy of the incoming cosmic rays (CR). A third omnidirectional counter (Sensor 3) serves as a proton monitor. The analysis of mass, energy, and incoming direction in combination with the directional geomagnetic cut-off allows the determination of the ionic charge of the CR. The ionic charge in this energy range is of particular interest because it provides clues to the origin of these particles and to the plasma conditions at the acceleration site. The experiment is expected to be flown in 1988/1989.

1. Introduction

In 1972 a new component of cosmic rays has been detected /1/, /2/ with a composition very different from solar or galactic cosmic rays. Because of the peculiar elemental abundances (predominantly helium, oxygen, and neon, no carbon) this component has been called "anomalous cosmic rays" (ACR). A current hypothesis associates the origin of ACR with the interstellar neutral wind. It is assumed that the neutral wind is ionized by solar I/V radiation and charge exchange with protons from the solar wind. After being picked up by the solar wind and the interplanetary magnetic field the ions (predominantly He^+, N^+, O^+, Ne^+) are swept to the outer heliosphere. There the ions (still being singly ionized) are assumed to be accelerated to energies high enough to re-enter into the inner solar system against the effect of solar modulation /3/. The first step of this process has, in fact, been observed recently for He with novel instrumentation onboard the AMPTE/IRM spacecraft /4/. Model calculations, including transport and acceleration are pretty successful in reproducing the observed spectra and abundances of ACR /5/, /6/. However, the determination of the ionic charge would give direct evidence for this hypothesis. Ionic charge measurements of solar cosmic rays carry important information on the plasma conditions (temperature, density) at the acceleration site on the sun.

In order to cover a large range in mass and energy the experiment consists of a combination of 3 sensors. A large area ion drift chamber (Sensor 1) and time-of-flight telescope (Sensor 2) are used to determine mass, energy, and direction of the incoming cosmic rays (CR). The energy and mass ranges of sensor 1 and 2 are listed in Table 1. Sensor 1 is optimized for the mass and energy range of the ACR component. Sensor 2 covers the full mass range between helium and iron at low energies. The omnidirectional Sensor 3 serves as a monitor to the proton radiation environment.

2. Ionic Charge Determination

The ionic charge, Q, of an incoming particle can be determined by simultaneously observing the magnetic rigidity $R = 43.3*(A/Q)*(E/A)^{0.5}$ and the energy per nucleon, E/A, where A is the atomic mass number. The instruments are designed to measure the energy, E, of each incoming ion. The mass (or nuclear charge) is determined by the well-known dE/dX versus E method (sensor 1) or by the time-of-flight versus E method (sensor 2). The magnetic field of the earth serves as a rigidity filter which gives access only to particles with rigidities exceeding the local directional geomagnetic cut-off rigidity. This is shown schematically in Figure 1. Only particles with R R_{cutoff} have access to the experiment. With E, A, and R_{cutoff} an upper limit for the ionic charge Q can readily be computed.

3. Payload Description

The main systems of the experiment are shown schematically in Figure 2. The experiment consists of 3 sensors, the sensor electronics, the central data system (DPU), a tape recorder for data storage and a battery package. The GAS payload will have a motorized door (MDA). Once in space the experiment is activated from the astronaut. This command enables MDA opening and turns on power to the DPU. The DPU then controls all 3 sensors and the data transfer to the tape recorder. At the end of the mission, the payload is returned to its quiescent condition ready for landing by another command of the astronaut. Figure 3 shows part of the experiment package in flight configuration: Sensor 1 (on top), the analog electronics (middle), and the battery box (bottom).

4. Sensor Description

A schematic diagram of Sensor 1 is shown in Figure 4. It consists of a three element ion drift chamber (IC1, IC2, IC3) with a thin entrance window (40μAl) followed by an array of 16 solid state detectors (SSD) and a CsI scintillation counter which is viewed by 4 light sensitive diodes. The first and the third elements of the drift chamber are sensed by two position sensitive proportional counters (PC1, PC2) with back-gammon shaped cathodes. In the first element also the drift time (TOD) of electrons generated along the track of the incoming particle is determined. The drift time is the time elapsed between the response of the SSDs and the anode of PC1. Drift time and position response of PC1 provide two coordinates for the incoming ion at the top of the sensor. At the bottom the position response of PC2 and the information on the detector row triggered by the incoming ion provide another two coordinates. From these 4 coordinates, then, the incident direction of the incoming ions can be derived. The ionization chamber operates with isobutane at a pressure of 75 torr (at 20 C). The density of the isobutane is actively controlled by a gas regulation system providing a continuous flow-through of isobutane. The gas supply consists of 180 g of liquid isobutane

stored in a Tl tank. The geometrical factor of the sensor is 35 $cm^2 sr$.

Figure 5 shows results from a calibration measurement at the Hahn Meitner Institue in Berlin. For this measurement a 800 MeV beam of S^{32} has been scattered on a thick target and the reaction products have been measured with the experiment. The figure shows a matrix of the ionization chamber versus energy signal and demonstrates the high mass resolution and low background of the system. In orbit the multi dE/dX - E measurement (PC1, IC2, PC2, SSD and/or CsI) will provide even better mass resolution and background rejection.

Sensor 2 (LAT) serves to identify and analyze the particles below 6 MeV/nucleon from H to Fe. The particles are identified by measuring the time, TOF, required to travel between a thin aperture foil and an array of solid state detectors. The timing signals are obtained from secondary electrons emitted when the particles penetrate the foil and the front surface of the solid state detectors: these electrons are accelerated and deflected onto microchannel plates which produce fast pulses suitable for START and STOP signals for a timing measurement. The solid state detector measures the kinetic energy $E = 1/2\ mv^2$ after taking account of the energy loss in the entrance foil and in the detector by nuclear defect. Since the flight path length between the foils and the detectors, λ, is known, the TOF and E measurements may be combined to yield the particle mass via $A = 2^*E^*(TOF/\lambda)^2$. In the configuration shown in Figure 6 the time-of-flight sensor has a flight path length, λ, of 50 cm, and a geometrical factor of 1 $cm^2 sr$. For a threshold of 0.3 MeV/nucleon for heavy ions, such a geometrical factor is large enough to analyze contributions from solar flare particles to the fluxes observed by sensor 1 above 6 MeV/nucleon. If a solar energetic particle event occurs during the mission, it would be possible to resolve isotopes of all elements from Helium through Silicon (and would resolve elements and some isotopes beyond Silicon). Figure 7 shows the He^4 track in a TOF - E matrix obtained from the prototype Sensor 2. The particles are from an alpha source. The alpha particles in the test pass through a variety of foil thickness to yield a range of incident energies centered around 0.6 MeV/nucleon. Notice the excellent mass resolution (σ_m = 0.06 amu) and low background in the matrix.

5. Acknowledgement

We acknowledge the effort of many individuals at the Aerospace Corporation, the Air Force Technical Applications Center, the University of Maryland, and the Max-Planck Institue für Extraterrestrische Physik who contributed to the design, manufacturing, and testing of the instrumentation.

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Table 1: $\sigma_m < 0.6$ AMU
(ADJACENT ELEMENTS RESOLVED)

Species	Energy Range (MeV/nucleon) Sensor I	Sensor II
^{4}He	3.5 - 95	0.30 - 6.1
^{12}C	6.0 - 150	0.36 - 8.9
^{16}O	6.8 - 120	0.40 - 6.6
^{20}Ne	7 - 100	0.41 - 5.6
^{24}Mg	7 - 100*	0.58 - 4.5
^{28}Si	*	0.43 - 3.85
^{32}S	*	0.46 - 3.10
^{56}Fe	*	0.56 - 1.26

*Separation possible only for every other element

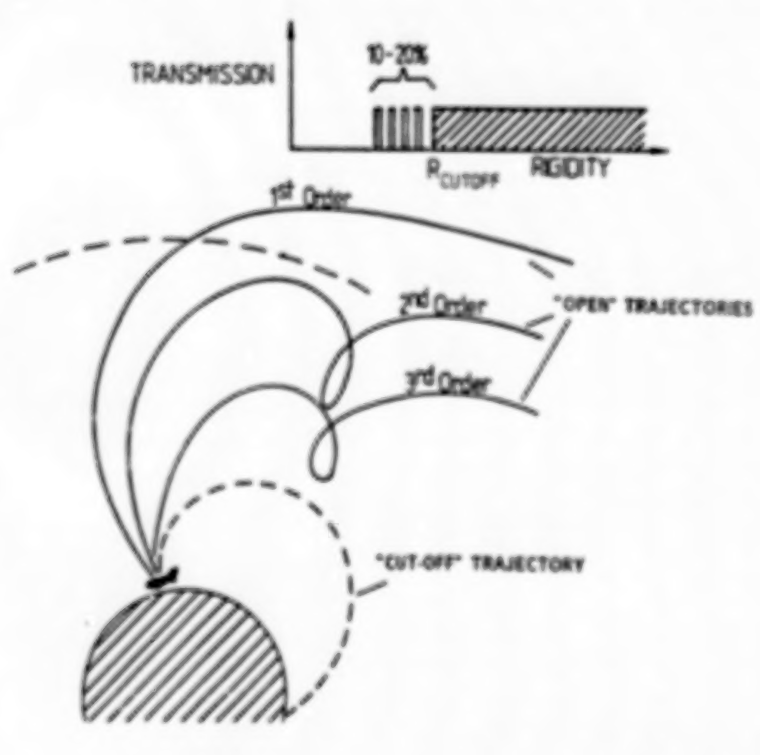

Fig. 1: Schematic picture of cosmic ray trajectories impinging from different directions with respect to the experiment axis.

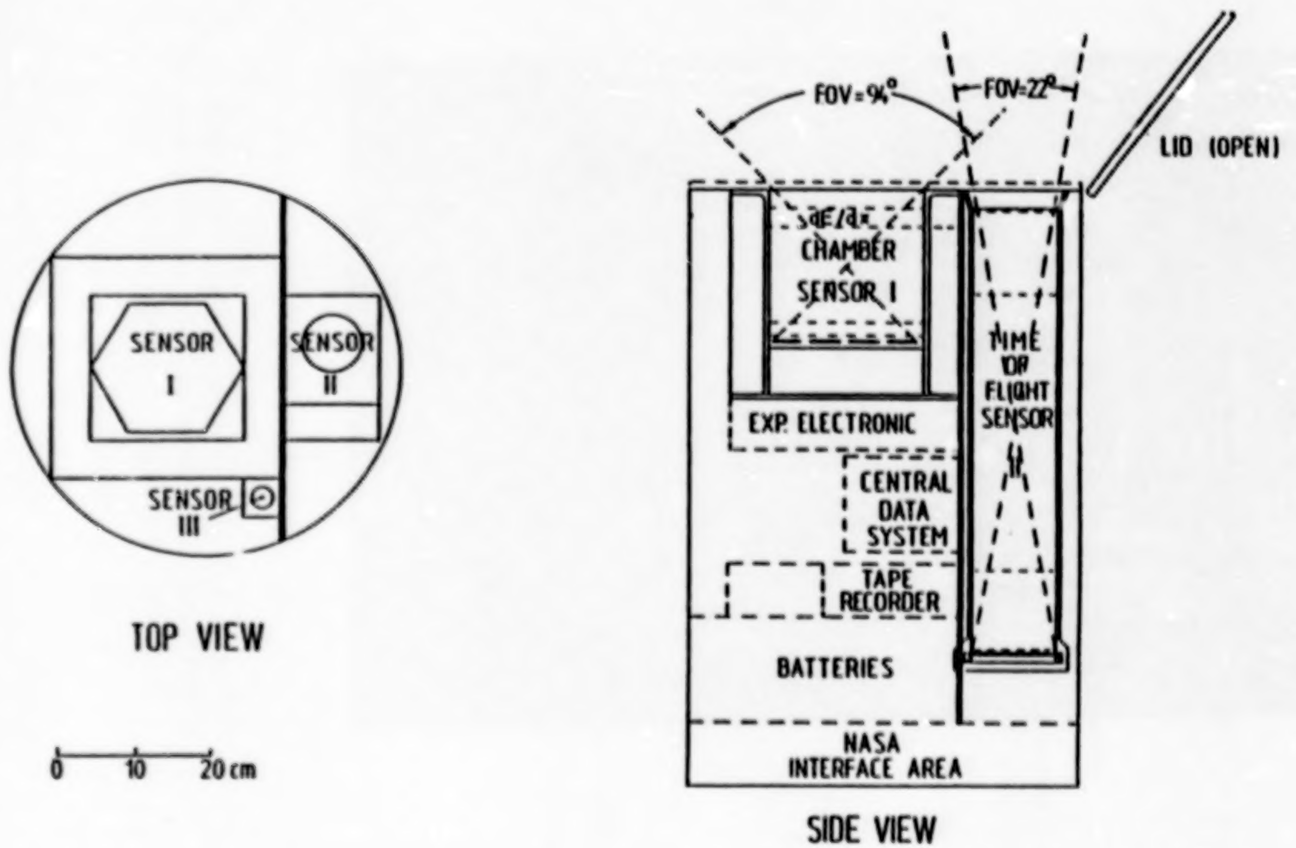

Fig. 2: Top and side view of the experiment package (schematic).

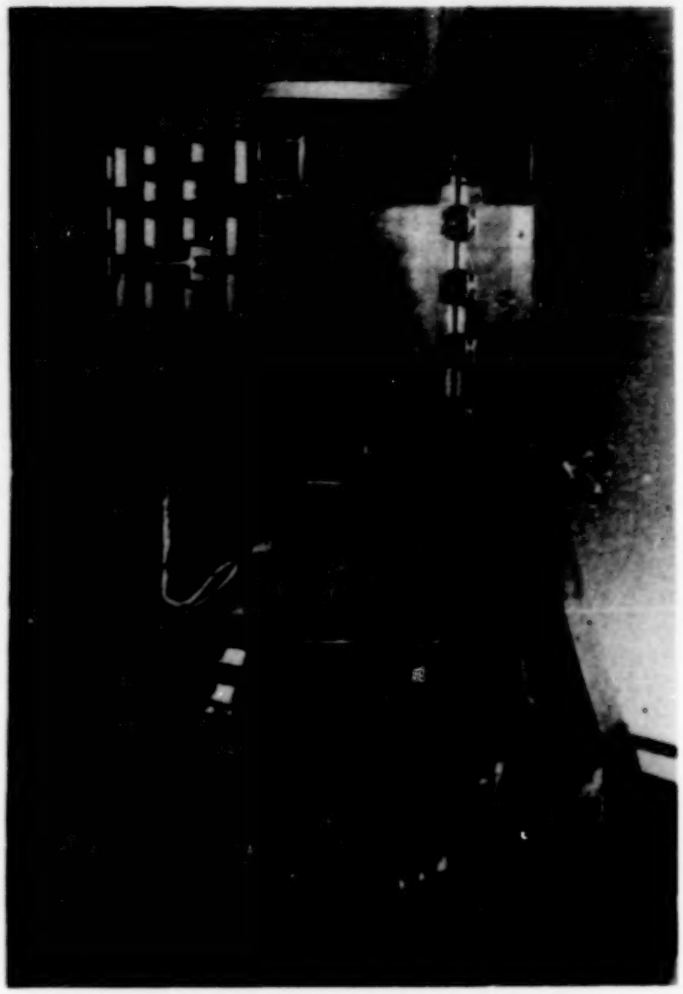

Fig 3. Sensor 1 (top), electronic box (without DPU, module), and battery box (bottom) in flight configuration.

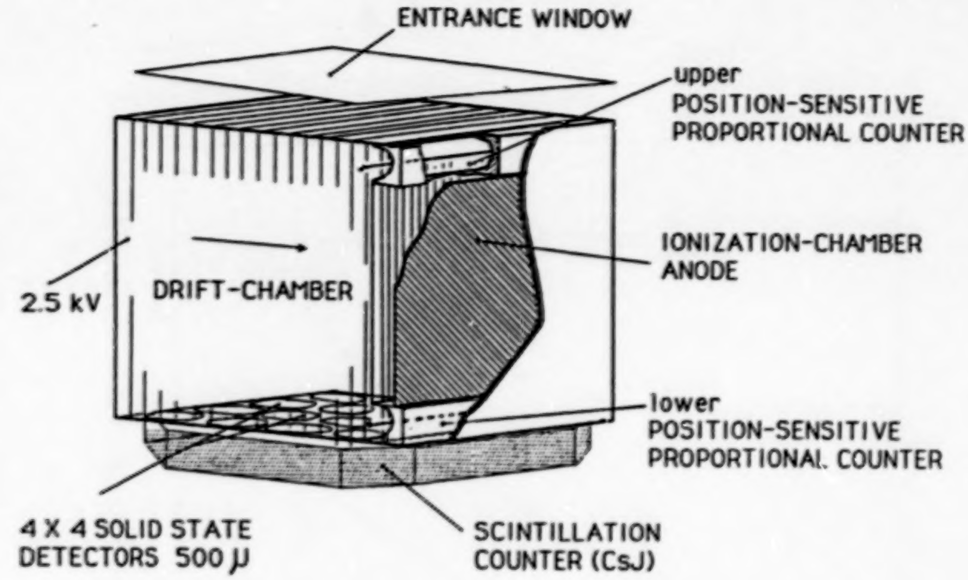

Fig. 4: Schematic view of sensor 1. The drift chamber size is 19 x 19 x 18 cm.

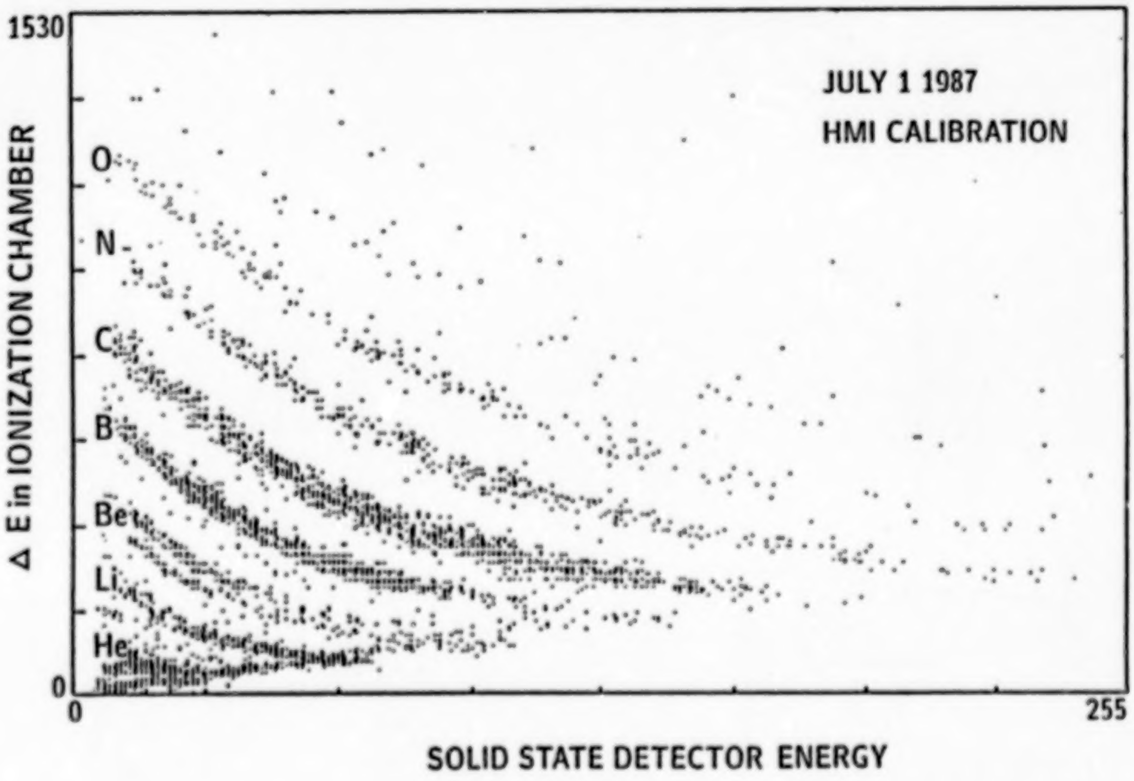

Fig. 5: Ionization chamber versus energy left in the solid state detector. Data are obtained with the flight unit at the HMI cyclotron in Berlin.

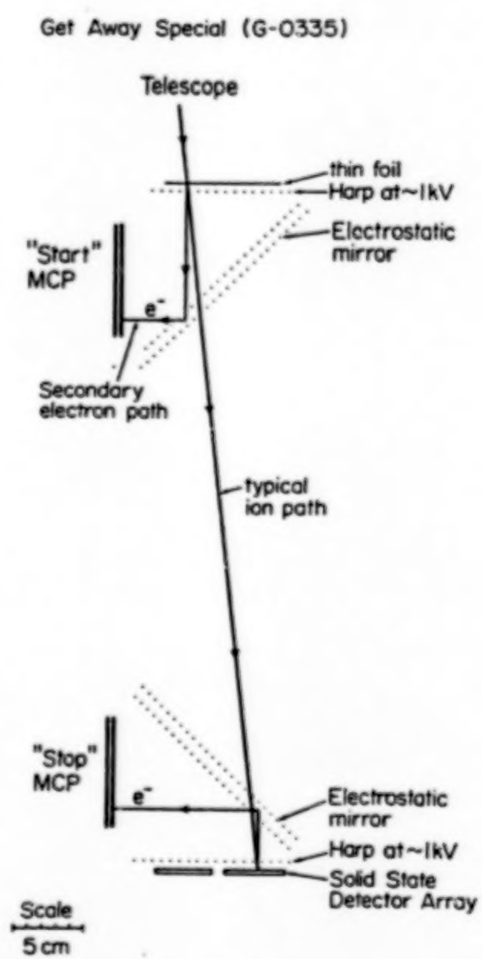

Fig. 6: Cross section of active elements of sensor 2.

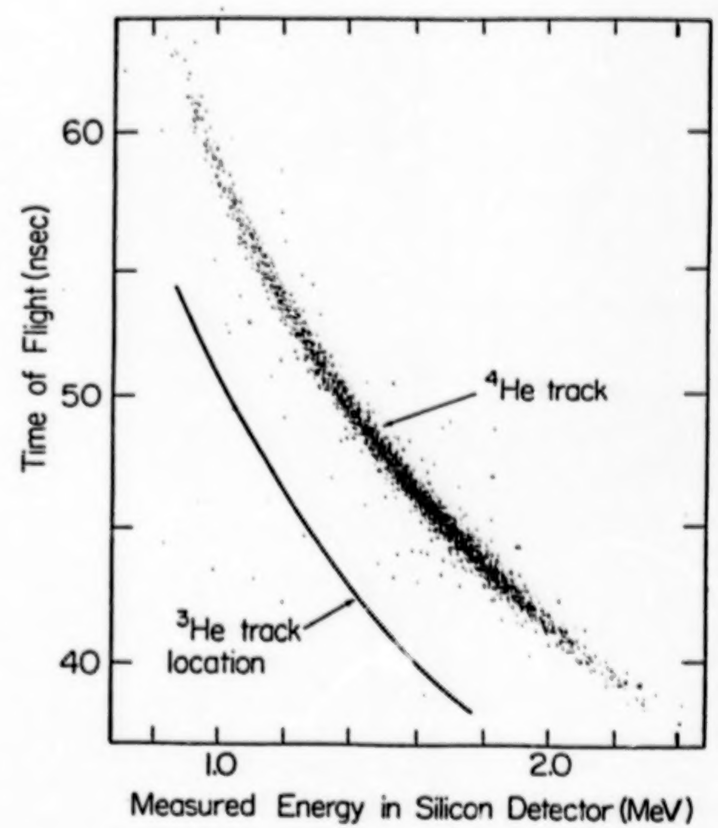

Fig. 7: Time-of-flight versus energy left in the SSD. Data are obtained with the prototype instrument using an alpha source.

N89-10909

CSCP

A NEW GET AWAY SPECIAL (GAS) PROJECT

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ABSTRACT

The Get Away Special (GAS) Program has instituted a new project called Complex Self Contained Payloads (CSCP) designed to support GAS type payloads that are beyond the scope of the GAS program. These payloads may be supported by GAS personnel and hardware and will fly as primary or secondary Shuttle payloads using the standard NASA Form 1628.

INTRODUCTION

The National Aeronautics and Space Administration's (NASA) Space Transportation System (STS) is built around a reusable vehicle called the Space Shuttle and is designed to provide routine access to space for a wide variety of payloads and users.

The Small Self Contained Payloads (SSCP) Get Away Special (GAS) Program was developed to provide certain types of payloads with a low cost way into space.

A review of the requirements of some GAS users has revealed that the very complex, classified or potentially hazardous payloads do not fit within the scope of the SSCP/GAS program. Further investigation exposed a definite need for a project that would support these payloads economically. It was then determined that GAS hardware and GAS personnel expertise would be an invaluable asset toward supporting these payloads.

The above considerations led to the decision to implement a new project within the scope of SSCP but apart from the GAS Program. This new project is called Complex Self Contained Payloads (CSCP).

PURPOSE

The purpose of the CSCP Project is to provide a flight carrier system and technical support to the user community whose small self contained payloads are complex, classified or potentially hazardous. The nature of these payloads precludes their inclusion in the GAS program. All CSCP payloads would be manifested according to the current NASA primary or secondary payload policies.

SSCP CLASSIFICATION

A. GAS - Candidate payload requirements for the standard GAS payload (Reference: NASA 14CFR Part 1214, Space Transportation System: Use of Small Self Contained Payloads) include:

1. The payload mission requirements are not Shuttle mission drivers.

2. The payload utilizes the normal GAS accommodations including optional services such as opening lid and ejection system.

3. The payload has no residual hazards.

4. The payload is not classified.

5. The payload can fly within the normal GAS queuing system.

B. CSCP - A payload may be a candidate for CSCP if it cannot fly in the GAS program for any of the following reasons:

1. The payload mission requirements may be Shuttle mission drivers.

2. The payload requires more than normal GAS accommodations but is still self contained.

3. The payload has residual hazards.

4. The payload is classified.

5. The payload cannot fly within the normal GAS queuing system.

CSCP Determination

GAS payloads and potential GAS payloads that are reviewed and are determined to be beyond the scope of the GAS program may be recommended for inclusion in the CSCP Project. A payload may also be considered as a candidate for CSCP on the request of the Payload Organization.

CSCP Requirements

Payloads that are identified for the CSCP project will have a Form 1628 (old Form 100) submitted to STS for approval. All payloads in the CSCP project may have use of GAS technical coordination, GAS carrier elements, GAS integration and preparation support as agreed upon by NASA Headquarters and the Goddard Space Flight Center. Specifics of the support will be detailed in a Support Requirement Plan (SRP) - an agreement between the customer and the CSCP. STS mission unique costs will be the responsibility of the payload organization. Each CSCP payload must maintain its self-contained concept and not require any services from the Shuttle other than mission timeline and safety considerations.

Each payload in the CSCP will require a separate STS Payload Integration Plan (PIP) and associated Annexes as well as a full phased safety review process. It is estimated that the CSCP Project will support two to four payloads each year based on the support requested.

CSCP Costs

The costs of the standard and mission unique support for each of the CSCP will be done on a case-by-case basis.

CSCP Participation

The CSCP Project proposes to provide the Basic Support Package (BSP) at a fixed cost. The BSP consists of:

a. Technical coordination and equipment compatibility reviews.

b. Payload carrier system.

c. Integration support at the Kennedy Space Center (KSC).

The CSCP Project may offer additional support on a limited basis, but not limited to, the following areas:

a. System safety support

b. Flight operations support

c. Unique flight and ground hardware

d. STS integration documentation

All requests for additional support must be agreed to by CSCP management and included in the SRP.

N89-10910

STS Safety Approval Process for Small Self-Contained Payloads

by

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Abstract

The purpose of this paper is to present to current and future users a description of the safety approval process established by the National Aeronautics and Space Administration (NASA) for Get Away Special (GAS) payloads. Although the designing organization is ultimately responsible for the safe operation of its payload, the Get Away Special team at Goddard Space Flight Center will act as advisors while iterative safety analyses are performed and the Safety Data Package inputs are submitted. This four phase communications process will ultimately give NASA confidence that the GAS payload is safe, and successful completion of the Phase III package and review will clear the way for flight aboard the Space Transportation System (STS) orbiter.

Introduction

All Get Away Special (GAS) payloads and canister hardware which are to be considered for space flight on the Space Transportation System (STS) must meet certain design criteria prior to flight and ground safety approval. The Goddard Space Flight Center (GSFC) Special Payloads Division is responsible for ensuring that each GAS payload assembly and its associated ground support equipment (GSE) is safe and complies with the requirements of NHB 1700.7, Safety Policy and Requirements for Payloads Using the STS, and STS Payload Ground Safety Handbook, KHB 1700.7.

Safety approval is typically divided into four steps, designated as Phases 0, I, II and III, which are reiterated as payload design is defined and gradually finalized, and as potential hazards associated with that design are identified. For most standard GAS payloads, the STS Safety Review Boards at the Johnson Space Center (JSC) and the Kennedy Space Center (KSC) become involved in the safety approval process only at the Phase III level of review; Goddard Space Flight Center is responsible for the intermediate 0,I and II levels of payload approval.

The results of each GSFC internal review and all hazard verification controls are incorporated into a final document, the Phase III Safety Data Package (SDP), and a Phase III safety review is conducted jointly with the Johnson Space Center for flight operations, and with the Kennedy Space Center for ground operations. For approval of more complicated payloads, JSC and KSC may participate much earlier in the process and would approve the payload at each level of review.

Payload Accomodations Requirements

The Payload Organization (PO) submits the first safety data as part of the Payload Accomodations Requirements (PAR) document. This occurs approximately twelve to fourteen months before launch, and corresponds to a Phase 0 level review. The purpose of the PAR is to identify major payload subsystems and to assess the applicability of a payload within the GAS program requirements and limitations.

Included in the PAR are a description of the payload hardware conceptual design, proposed operational requirements, and any safety related conditions or possible areas of concern. It is not important that all pertinent information be available at Phase 0, simply that a cursory look has been given and will be updated as other safety concerns become apparent throughout the process. This information is reviewed by GAS flight and ground operations personnel, GAS and JSC safety engineers, and the NASA Technical Manager (NTM), who is the single point of contact between GSFC and the PO. All comments from these participants are incorporated and finalized as a baseline PAR.

Phase I (Preliminary Design)

The Phase I iteration of the safety review process, submitted as a Preliminary Safety Data Package, provides more information on the safety critical components and operations of the GAS payload. A more detailed device description, hardware sketches and other preliminary illustrations should be included as part of this document. Potential payload-related hazards and proposed safey controls and inhibits should be discussed, and a hazard control verification plan developed for evaluation. Hazard reports for each identified hazard should also be submitted with the Preliminary Safety Data Package.

Hazards are categorized as either critical or catastrophic. A critical hazard is defined as anything that could cause unintentional damage to the orbiter, proximity payloads or the GAS container itself. Critical hazards must be controlled to one failure tolerance, meaning the payload must remain safe even after one credible component failure. Those hazards which could result in personnel injury, loss of the orbiter, or destruction of STS and other equipment are considered catastrophic, and must be shown to be two failure tolerant. The data provided by the PO must substantiate the above when addressing each potential hazard.

The Preliminary Safety Data Package is distributed to members of the GAS team for independent review. A joint review is then held with the NASA Technical Manager and GAS safety and operations personnel to discuss questions or areas of concern regarding the information provided. Pertinent GSFC technical experts are also available for consultation if necessary. The Payload Safety Officer (PLSO) incorporates all comments from this review into one marked-up version of the safety package, which is sent to the Payload Manager along with a letter of clarification of those comments.

Several weeks after the SDP is returned to the Payload Organization, a telephone conference is scheduled by the NTM and Payload Manager to discuss any questions the PO may have concerning the GSFC Phase I review. This discussion is typically focused on the incorporation of additional information in preparation of the Final Safety Data Package required for Phase II of the review process.

<u>Phase II (Final Design)</u>

At Phase II, fairly detailed hardware illustrations, system or subsystem block diagrams, and detailed schematics showing the necessary hazard controls are required. As payload design proceeds, more detail is needed on hazards that could affect STS flight and ground operations and crew. Payload descriptions must begin to include specific information about payload subsystems, potential hazards and proposed controls, and methods of verifying hazard controls.

During this period, the payload organization must begin to submit a reviewable summary of each hazard verification method. This information would include, for

example, structural and other analyses, a parts and materials list of all payload components, and results of such things as vibration testing, leak and proof pressure testing of sealed containers, and functional testing of fuses, temperature and low voltage cutoffs, and other battery or circuitry malfunction controls. These summaries are reviewed, independent of the payload organization, to ensure that the data contained therein is complete and accurate, and successfully meets the requirements for controlling hazardous functions or subsystems. Copies are kept on file with GAS safety engineers for future reference if necessary.

As before, GAS safety engineers independently review the system inputs, recommend changes or additions to the identified hazards, and review and approve the safety verification of these hazards. The PLSO incorporates this data into a marked-up copy of the Final Safety Data Package which is again sent to the Payload Manager via the NTM. Another telephone conference is scheduled to clarify any questions about the Phase II review and discuss additional information needed to prepare the Phase III Safety Data Package, including completed hazard reports, for submittal to the JSC and KSC Safety Review Boards.

<u>GSFC Phase III</u>

The Phase III Safety Data Package is the final submittal of safety information. It states that adequate analysis and testing of the GAS payload has been performed and identifies all hazards that could be associated with the operation or malfunction of the payload or payload component. The Phase III package must include a detailed discussion of appropriate safety measures which have been implemented to effectively eliminate or control these hazards.

Each hazard report is considered a stand-alone document at the Phase III level. All credible failure modes of a payload must be identified by this point, and the hazard potential of each specific failure must be assessed. Hazard controls and methods of verifying that those controls are in place and operational are established to ensure that all unsafe conditions are inhibited to an acceptable level of safety risk, i.e. one or two failure tolerant. Verification methods may include tests, analyses or inspection, and similarity to other payload designs may sometimes be used if approved by the GAS and STS Safety Review Boards.

The status of each verification method must be tracked as payload design proceeds. An item is considered to be "open" until a test or analysis is complete and the results have been submitted and approved by GSFC. In general, all verification methods must have a "closed" status before Phase III safety approval will be given. Along with a "closed" status, supportive data for each method of hazard control verification must be included for future reference or auditing. This data would include, but is not limited to, test and analysis report numbers, inspection procedure numbers, quality control log book references, drawing numbers and completion dates.

In some cases, the Phase III Safety Data Package may be submitted to the STS with "open" status items. For example, procedures which are to be performed as part of final payload preparation at KSC would remain "open" until payload close-out. However, a copy of the procedure must be on file with GAS personnel, and reference to the specific procedure number as part of the hazard report is required.

STS Phase III

Upon GSFC Phase III approval, the Phase III Safety Data Package is submitted by the GAS project to both the KSC and JSC for review. Included with this submittal are a signed Certificate of STS Payload Safety Compliance signed by the GAS Project Manager, and a letter of approval from the GSFC Materials Control and Applications Branch for all parts and materials used on the payload.

KSC reviews are focused on potentially hazardous ground payload processing operations such as battery top-off charging and hoisting, and the use of other ground support equipment and tools brought to KSC by the payload organization. The JSC safety board reviews payload flight operations for compatibility with manned-flight requirements and regulations, and ultimately determines that a payload is safe for flight aboard the STS orbiter.

These reviews are typically handled administratively between NASA centers, however in some cases a formal review may be required. If so, the appropriate GAS safety personnel would meet with STS safety personnel to clarify any outstanding issues and generate an acceptable, approved Phase III Safety Data Package.

As part of updated post-Challenger documentation requirements, those GAS payloads which had previously been approved through STS Phase III prior to January 1988 are now required to submit a Delta Phase III Safety Data Package. The purpose of this additional step in the aproval process is to ensure the STS safety boards that the payload has been reevaluated and remains in compliance with NASA safety standards and regulations. Prior to STS resubmittal, new signatures of approval are required from the GAS Project Manager, GAS Safety Engineer and the GSFC Materials Control and Applications Branch for reexamined parts and materials usage.

Post Approval

Receipt of STS flight and ground safety approval is the final step in the review process. The GAS payload is then appropriately inserted into the GAS manifesting queue to await a flight opportunity. Once manifested, the Payload Organization delivers the payload to KSC, where final preflight inspection is performed by the GSFC. In some cases, a verification or demonstration of the hazard controls referenced in the safety documentation may be requested. This inspection verifies that the payload is exactly as described in the safety information previously provided, and is indeed safe for STS flight.

Conclusion

The four phase safety review and verification process established for small, self-contained payloads, and specifically Get Away Special payloads, is an important process which ultimately gives NASA confidence that a GAS payload assembly is safe and is in compliance with STS safety regulations as defined in NHB 1700.7 and KHB 1700.7. The requirements set forth by NASA in those documents are intended to protect flight and ground personnel, the STS, other payloads and associated ground support equipment and the environment from payload-related hazards.

The information provided in the Safety Data Packages should become more specific and complete with each successive step in the approval process. For each phase of review, the Get Away Special team at Goddard Space Flight Center will act as advisors while iterative safety analyses are performed and these Safety Data Package inputs are submitted. Several iterations help to ensure that all potential hazards associated with a GAS payload have either been eliminated by design, or are controlled to an acceptable level of risk.

By establishing regular safety communications early in the system development, the payload organization will benefit from GSFC and STS safety engineering experience, and therefore possibly avoid costly or time consuming design errors; cooperation throughout this communications effort will result in a GAS payload design which is considered safe and flight ready. Upon successful completion of the Phase III Safety Data Package and review, the GAS payload will be appropriately inserted into the GAS manifesting queue, and will ultimately be awarded a flight opportunity aboard the STS orbiter.

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1) NHB 1700.7 "Safety Policy and Requirements for Payloads Using the Space Transportation System"

2) KHB 1700.7 "STS Payload Ground Safety Handbook"

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N89-10911

SYSTEMS REPORT FOR PAYLOAD G-652: PROJECT ORIGINS

J. Bellina, M.D., Ph.D., M.C. Muckerheide, J. Clark, M. Petry, D. Seeley, R. Sportiello, R. Sprecher, M. Theiler

This paper reports on experiments conducted during the past year which investigated possible hardware configurations and methodologies for our payload project.

Test Data collected from the operation of a free electron laser wiggler using simulated ram glow phenomenon are described.

Results of an experiment to synthesize organic compounds within a primordial atmosphere using a laser induced plasma are discussed.

An experiment is described which utilized neutron bombardment to assess the risk of genetic alterations in embryos in space.

Because of limited space for the amino acid experiments, we have configured the device with a major effort toward miniaturization. The original single chamber concept has been eliminated to prevent a large array of chemical and gas storage along with robotic measuring devices which could encumber the experiment. Collection of the amino acids from a single chamber also is difficult. Therefore, various gas and chemical mixes will be housed in small 2cc vials which will be irradiated by laser to produce a small plasma within them. This configuration allows us to have the samples already collected and isolated after the plasma (spark) has caused the combination to occur.

The failure of mixing because of valve or relay latch up from a dispenser array is eliminated and discrete amounts of the elements can be stored in minor amounts thus eliminating the hazards associated with large volumes of gases.

The laser initiated plasma (spark) is easily positioned within the 2cc vial as is shown in Fig. I.

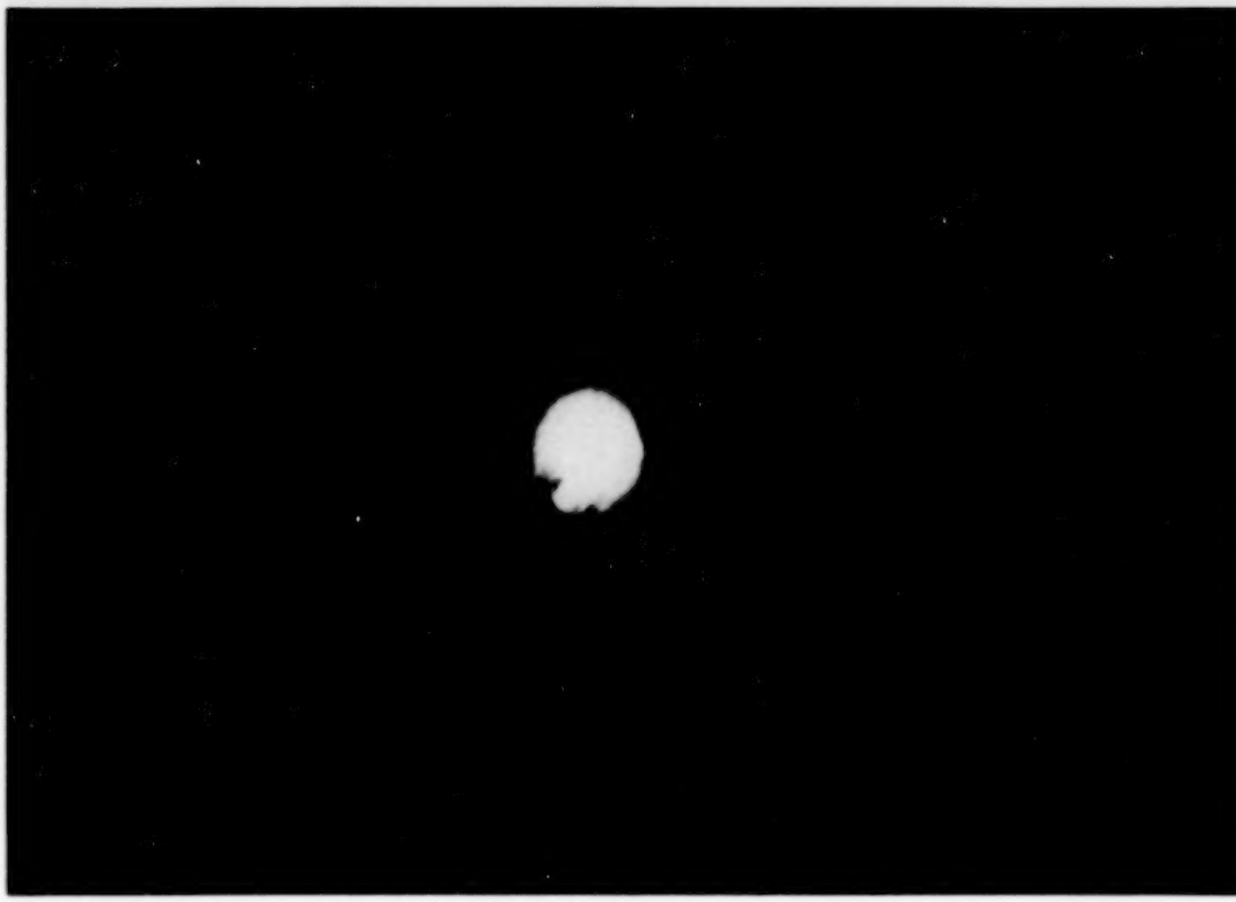

Fig. I
2cc vial with laser initiated plasma within the vial and gases with an electrode free environment.

The original experiment in the 1950's produced amino acids by introducing an electrical spark into a chemical environment which replicated the primordial atmosphere. The problem as we see it with such a device is that the electrodes themselves boil off, or sputter metallic material into the environment. The use of a laser spark (plasma) within a vial containing a chemical atmosphere eliminates the electrode variable in the experiment and allows us to look closely at the combined materials minus the electrode contaminants. Care must be taken to prevent the laser induced plasma from contacting the vial wall as is seen in Fig. II. Contamination of chemical atmosphere could result from contact of the plasma with the vial wall.

Fig. II
Improper focusing of laser light results in plasma production too close to vial wall.

The free electron laser wiggler configuration was introduced into a vacuum chamber and the remaining gases excited with high voltage. The magnetic lines of force were evident as they related to the magnetic array.

In near earth orbit, our GAS payload will be subjected to a cosmic ray flux of nearly 2000 impacts per square meter per second. These cosmic rays are known to consist primarily of protons and alpha particles, travelling at very nearly the speed of light. It is virtually impossible to simulate this environment on the surface of the earth. In an attempt to assess the effects of cosmic ray bombardment on a biological sample, we have placed biological samples in a neutron howitzer.

The neutron howitzer used contains a 5 curie plutonium source, mixed interstitially with beryllium. This results in the release of about ten million fast neutrons per second, which are moderated by a water jacket, and also gamma rays. The biological sample was placed in proximity to the neutron source, so that it was irradiated by thermal neutrons and by gamma rays, as a simulation of the actual cosmic ray bombardment that will be encountered in orbit.

Neutron and gamma ray bombardment of biological samples in order to assess the risk of genetic alterations in space due to cosmic rays has limitations. In our case, the result of placing the biological sample in the howitzer was the death of the sample in a manner of minutes. As a form of ionizing radiation of very high particle energies, cosmic rays should pose a risk of genetic alterations in biological samples. This thesis will be tested in earth orbit.

For the actual experiment, we have chosen to place the embryos in several cylindrical vials, surrounded by a detector stack consisting of CR-39 and Lexan. In this way we hope not only to gain information regarding the number of hits suffered by our sample, but also the trajectory of the cosmic ray particles. Subsequent microscopy and/or electron microscopy could further aid in determining the effects of cosmic rays on the genetic structure of the samples.

N89-10912

GAS-611
FIREFLY IN ZERO GRAVITY
PROJECT MGR: TONY WILLIAMS

DELTA-t
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ABSTRACT:

A study of Insects in a Micro-Gravity environment has not been investigated to date. There have been some short duration experiments on animals and plants. Long duration ZERO-G exposure was made possible through the NASA-Space Transportation system utilizing the Space Shuttle Orbiter. The effects of micro-gravity on living organism can only be tested over a long duration. Then, reliable data can be obtained and applied where needed, possibly assisting in the attempt to safely colonize Space. Many material,man-made and natural,exhibit different characteristics when introduced to weightlessness. Mechanical properties that are associated with some materials become obsolete. The effects of "gravitational pull" is found throughout the Universe at many different levels. With the exploration of deep Space at our door step, understanding microgravity is a new challenge to 'Today's Engineer'. NASA made available the largest microgravity laboratory known to man and now challenges him to explore it's secrets. The study of processing materials in space can start with experiments that are biological in nature. GAS-611 Project will carry a small, self-contained, biological experiment into a microgravity environment for a period of 120 hours. The payload will be a colony of "Lampyridae", commonly known as the Firefly or 'lighting bugs'. The ability of this beetle to produce light, with an efficiency of 98%, will be evaluated in a micro-G environment. The chemical process that occurs could be assisted by Mother Earth's Gravitational pull and the very complex tracheae system found within this species of Beetle. The ability to place "Natures Light" next to a Star could only happen in dreams, until NOW!

Funding for this project is assisted by the sale of GENERIC CADD drafting software.

Objectives: The Firefly in Micro-Gravity

- -What is the effect microgravity has on the ability of the Firefly to produce light? Can this effect be quantitatively measured?
- -Does microgravity effect the insects ability to function?
- -Is the larva of the Firefly effected by microgravity?
- -With the absence of thermal convection, is the Firefly affected in an way? Can this condition be determined?
- -What are the effects of the extreme G-forces introduced during the launch, on the firefly?
- -Does the Firefly respond to vibration in space the same way it responds on earth?
- -Is the Mating ritual the same in space as on earth?
- -Was mating successful? Are there any side effects after the space exposure?

MICROGRAVITY: (17)The Lewis Research center in Cleveland Ohio, has a fully equipped laboratory to conduct research in a microgravity environment. Working in close proximity with NASA, this facility can provide from 1 second to 20 minutes of microgravity. The space shuttle program made available the extended duration of microgravity that is needed to study biological as well as materials and processing techniques. The advantages to studying the effects of microgravity on earth related materials is complicated by the required Space Application Engineering needed to construct the Environment that houses the experiment. The engineering techniques, used on earth may not apply when subjected to a Zero "G" environment. The effects of 'Shuttle Launch' can vibrate the entire Payload apart. Electronics will self destruct if not properly designed for temperature compensation. These are only a few of the design parameters that surround a Space exposure experiment.

The children of today are the engineers of tomorrow and the future Space Application Engineers must be nurtured and motivated,because they will be provided with the challenge to become a 'Modern-Day Pioneer' in the 1990's. The responsibility to future exploration can only be guaranteed if today's youth is motivated and challenged.

BIRTH OF THE GET-AWAY SPECIAL PROGRAM: In 1972,NASA was given the assignment to develop a reusable space vehicle that could carry large,heavy scientific experiments,and manufacturing facilities into low earth orbit. The space shuttle that was selected by NASA for the Space Transportation System is built around a reusable space vehicle called the Orbiter with expendable external tanks and two reusable solid rocket boosters. The Orbiter, which is approximately the size of a DC-9 aircraft, contains a crew compartment, that can accommodate up to 7 crew members,and a 60 foot long by 15 foot diameter cargo bay, designed to carry 65,000 pounds. The cargo bay doors will open in orbit to permit a variety of experiments, investigations, and space applications. (14) In accordance with national policy, NASA must be reimbursed for providing launch services to non-NASA

customers. The pricing policy which NASA implemented is designed to recover the Space Shuttle operations cost over the defined 12 year operational lifetime of each Orbiter. The load factor per flight,based on either the length or weight of the payload, averages between 60% and 80%. This was the basis for establishing the pricing formula for major payloads.(10)The Shuttle reimbursement policy principle, recovers the projected average cost per flight whenever the cargo bay is 75% utilized ($1300 per lb). Since the remaining space was not required to produce revenue, the idea evolved that it could be used to provide opportunities to fly payloads of a small size, at a very low cost per pound (10) ($50.00 per lb); provided limited Orbiter services and resources such as power,crew support and deployment would not be required. (14)The objective for providing this opportunity, was to encourage the use of space research by educational institutions,small companies,organizations,and individuals that could not possibly afford the investment required to fly a major payload. These Payloads could Generate new Activities unique to Space,(GAS) thus providing the stepping stones to deployment of larger scientific or commercial payloads on future shuttle flights. To accomplish this objective NASA established the criteria that payloads of this class must be for scientific research and development purposes. NASA will not attempt to judge the scientific merit of a proposed experiment. All users will be required to furnish NASA evidence of scientific research and development intent and sufficient information for verification by NASA that the payload is for peaceful purposes and complies with applicable law and policy.

The Small-Self Contained Payload (SSCP) or Getaway Special program opened the Mysteries of the Universe to anyone who dared to challenge her.

EVOLUTION OF A PROJECT: (9) Working with the experimenters handbook a rough estimate of the thermal requirements can be obtained. (see Fig-A) 2.5 cubic foot container,with an insulated end cap,requires 15 Watts/hr. to maintain 26 degrees centigrade. Since the heating requirements will only be needed during the actual mission and a conservative estimate of 120 hours is established. A 1.8KWH battery pack will be needed for heating. The housekeeping requirements of the avionics,needed to control this payload will increase the battery pack to 2.0 KWH capacity.(Based on 5vdc@ 333ma continuous 120 hours). With this information the weight and volume of the batteries can be found in Graph B. Prior GAS payloads have used, NASA approved, Silver-Zinc (Ag-Zn) with much success. The weight of the battery pack is approximately 30 Pounds. The volume of these batteries will be 0.4 cubic feet,without containers and mounting hardware.
Structure weight estimate:Aluminum 6061-T6 (NASA approved)

Density= 0.098 lbs/in3 (44.49 gm/in3) (11)

V=3.1415*R2*L A=3.1415*D2/4 M=L*roh*3.1415*R2

The Shelves:Diameter= 19.0 inches Thickness= 0.125 inches

(these dimensions contingent on Stress Analysis)

L=0.125in pi=3.1415 roh=0.098 lbs/in3 radius=9.5 in.

Mass s= 0.125*0.098*3.1415*90.25

Mass s=3.34 pounds for each shelf(using 4 shelves=13.89 lbs)

Side Brackets: Using a Symmetrical 'T' shaped bracket (also contingent on stress analysis.)

Length=0.75 in. Thickness=0.25 in. Height= 14.00 in.

Mass b= (2*(0.250*0.75)*14.0)*0.098

Mass b= 0.5145 pounds each (using 6 brackets= 3.087 lbs

Total Structure weight: Mass t= 13.89+3.087

= 16.977 pounds (occupying 0.1 cubic feet)

The experiment recording system will be a 35mm camera with a close-up lens,autowinder and a special 250 film pack. The film is used to record numerical data via LCD display in the field of view of the camera. This method is a simple and permanent form of data storage. This system may be replaced by a video camera / recorder if the weight limit is still maintained.

The avionics and recording weight is estimated to be 3.0 pounds. Actual weight of the electronics package is not calculated for this presentation. The weight of the recording system was determined by the shipping weight of a complete AE1-Program camera outfit from a mail order house.

Weight of the Enviro-Chamber: Structure= 4 Shelf ===> 13.890
Pounds 6 Brackets=> 3.087 "

	Total ===>	16.977	"		
Batteries=		30.0	"	Weight Limit	60.0 lbs
Recorder & Avionics		3.0	"	- total	50.0 "
Total SBR		50.00	"	Enviro-Chamber	10.0 "

The Get-Away Special program has a size and weight parameters that are within the guidelines of the space transportation system. The model presented is the first pass attempt to establish the direction needed to obtain the required design for reliable payload results. The smallest payload parameter, offered by NASA, was selected as the starting point for this project. (9) Payload Envelope Parameters:Container Size 19.75" x 14.13" Weight limit 60 lbs---- 2.5 cu ft.

The payload will be completely self-supporting,with 3 electrical controls to be operated by the Astronauts. (9) The NASA supplied container,that houses the payload, is made of aluminum with an insulation on the exterior. The mounting plate is 19.75" x 0.625" thick aluminum with purging ports and can not be altered by the experimenter. The inside of this container will maintain 1 atmosphere of dry air throughout the entire mission. This experiment requires an environment that can sustain the life of insects for 15 weeks. The total time in a microgravity state will be 4 to 7 days. This will occur approximately 75% into the 15 week mission. Temperature of the enviro-chamber will be 26 degrees centigrade for the entire 15 weeks. Strip type heaters will be activated by a high/low thermostat to maintain this temperature. In the event the temperature rises too high, then a small fan will be activated, by the thermostat, inside the avionics bay.

ENVIRO-CHAMBER DESIGN: Based on a 10 pound limit and a remaining volume of: (Fig-C)

Structure	= 0.1 cubic feet	
Battery	= .5 " "	(19"dia.x 3"high)
Recorder/Avionics	= .82 " "	(19"dia.x 5"high)
total SBR	= 1.42 cubic feet	
Volume limit	= 2.50 cubic feet	
minus total SBR	= 1.42 " "	
Enviro-chamber	= 1.08 cubic feet	

The chamber construction will be made of wood for this model. It's dimensions are 12" x 12" x 5" Square.
White Pine Density = 0.0156 lbs/in3 (11)

Sides: 5"* 12"* 1"= 60 in3* 2 = 120 in3*0.0156= 1.872 lbs
5"* 10"* 1"= 50 in3*2 = 100 in3*0.0156= 1.560 lbs
Top & Bottom : 10"* 10"* 1"= 100 in3 * 0.0156 * 2= 3.120 lbs
Total = 6.552 lbs

The inside of the chamber will be lined with moist earth. The soil will be retained in a 'mesh' envelope and will have the necessary Nutrients to sustain the insect's diet. For this model the density of Moist Earth=0.0451 lbs/in3 (11).

Plates: 3"* 10"* 0.25"=7.5 in3 *4 = 30 in3* 0.0451 = 1.353 lbs
10"*10"* 0.25"=25 in3 * 1 = 25 in3* 0.0451 = 1.128 lbs
(bottom only)
Total = 2.481 lbs

Weight of the Wood structure and the lining plates = 9.03 lbs

The inside of the walls will have 3 slots milled 0.5"wide x 10.0" long x 0.5" deep to provide a natural 'Crevice'(1)habitat the insect is familiar with. The weight of the enviro-chamber is reduced by the slots and the opening of the Camera system by 0.935lbs. These 'roads' will also be linked vertically and will be constructed such that when traveled the insect will be directed to the open chamber where the recording system can document their activity. The bottom plate will have a water seeding system, consisting of a simple 'Wick' laced within the plate. This will provided needed moisture for some humidity. (18) It must be noted that the dry air used by NASA has a Dew point of -76 degrees Fahrenheit. This condition is not desirable inside the Enviro-Chamber as it could cause dehydration.

In the center of the open chamber is a four sided pyramid, coated with mirrors to provide the 'window' to observe the inside of the entire chamber. The water seeding bag will be housed by this structure. The water seeding bag requires a special valve that prevents it from emptying at launching because of the large 'G' force imposed on it. A heater will be mounted on the bottom side of the top cover and will be controlled by a thermostat near the center of the chamber. Additional heaters will maintain the outside temperature of the enviro-chamber. This method of maintaining the payload temperature will reduce the thermal gradient of the internal payload structure and transfer the

additional stress to the NASA supplied canister. A composite material will be used to further insulate the remaining volume of the Enviro-Chamber Bay. Weight is the determining factor.
COSTS:Design,and Construct or Lease the Equipment? The success of an individual is determined by that individual's ability to find a need and fill it. With the introduction of the GAS program,the emergence of unique support groups have evolved. The GAS Program is a small part of a very large unit called NASA. The program is structured to accommodate the experimenter and allow a simple idea to expand to a full project without the red tape associated with a typical Military space experiment. The redundancy has been left out. There still are many requirements for a GAS project. The safety manual is 200 pages not counting the continuous flow of mail that is termed 'associated' with the GAS program. The money charged,by NASA ($3000.00 for this Project) for it's role in a project,can be considered to be the best-deal-in-town, because the support provided by NASA is far greater than the actual charges. To the new user this may not be evident when first introduced to the program. Many times NASA officials will verify a particular part or material to assure it is safe to use in the environment of space. The key too pushing a project through the portholes of NASA Safety program is to use materials and methods already approved. Re-inventing the 'so-called wheel' methodology is not a cost effective thing to do when designing a Space exposure project. The cost start to escalate when one tries to shrink a full size 'earth environment' into 2.5 cubic feet with a maximum weight of 60 lbs. (9) The cost of Silver-Zinc batteries for this project,based on 2.0 KWH will be about $1800.00 (1979-dollars).
A typical, commercially available, Data recorder ranges from $1500.00 to $55,000.00 and not only carries a hefty price tag but weighs a TON. The INDIVIDUAL-OUT-OF-POCKET raw cost to complete this project is $25,000.00. With the support of 'sponsors' this projection could be on the high side.

There is an alternative, three companies will provide their expertise and lease an experimenter a complete payload integration service,tailored to the user's requirements. The paper work with NASA is also handled so the user can concentrate on the Experiment.

Who's Who:	Vendor		Cost for services
	Instrumentation Technology		Start at
	Associates(ITA-Exton,Pa)	------->	$55,000.00
	Getaway Special Services	------>	$35,000.00 to
	Bellevue,Washington		$50,000.00
	MBB-Erno	----->	Start at
	Germany		$100,000.00
	Quartic Systems	Has an Electronic computer/recorder	
	Salt Lake City	that draws 15 milliwatts. (NICE)	

The dollar value may be considered high when first reviewed but for a ONE TIME experiment these services could save much time as well money. The experimenter that establishes the requirement of multiple flights would reuse his original Payload canister.

ORIGINAL PAGE IS
OF POOR QUALITY

GET AWAY SPECIAL
SMALL SELF-CONTAINED PAYLOADS
2 1/2 FT³ CONTAINER WITH INSULATED END CAP

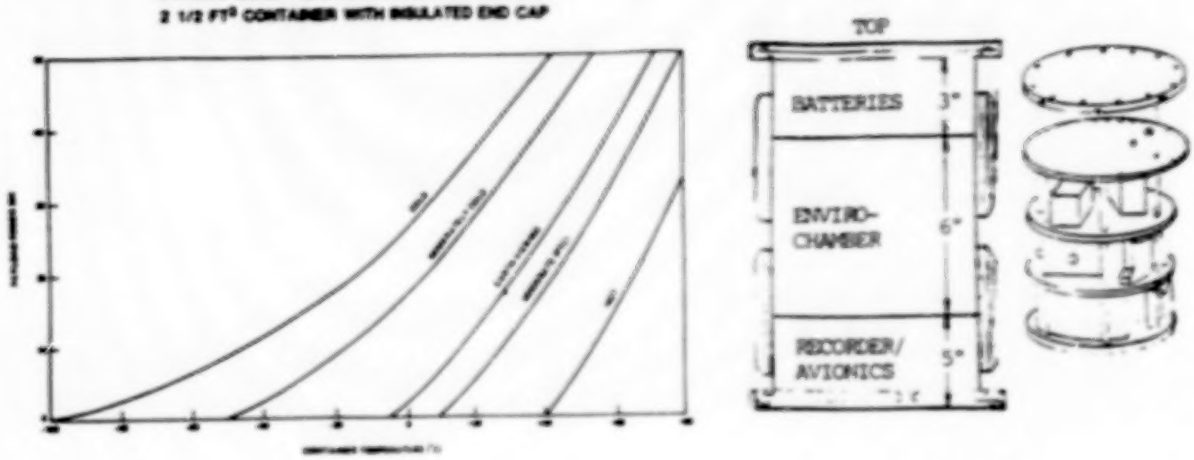

FIGURE A

FIGURE C

GET AWAY SPECIAL
SMALL SELF-CONTAINED PAYLOADS
BATTERY DATA

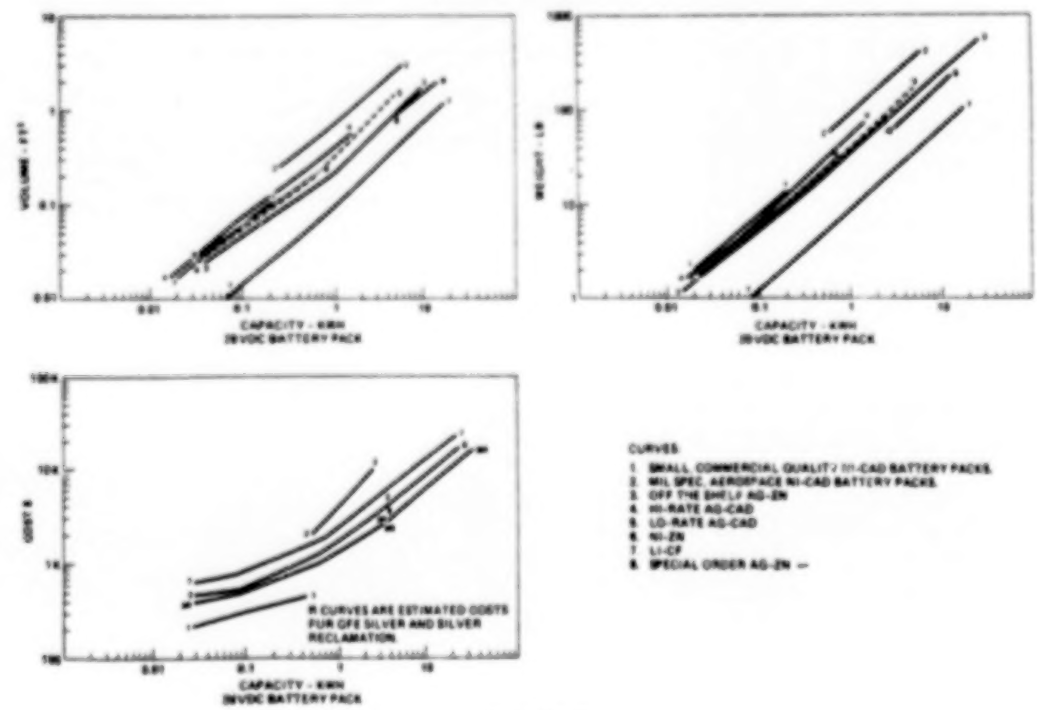

FIGURE B

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September 1985
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death of the Colony of Ants June 18,1983
18 by Students of Camden High School and
Woodrow Wilson High School

N89-10913

ACCELERATION GROUND TEST PROGRAM TO VERIFY GAS PAYLOAD NO. 559 STRUCTURE/SUPPORT AVIONICS AND EXPERIMENT STRUCTURAL INTEGRITY

Paper to be Presented at the 1988 NASA GAS Symposium

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ABSTRACT

Acceleration ground tests have been conducted on GAS Payload 559 to verify the structural integrity of the structure/support avionics and two of the planned three flight experiments. The ITA Standardized Experiment Module (ISEM) structure was modified to accommodate the experiments for P/L 559. The ISEM avionics consisted of a heavy duty silver zinc power supply, three orthogonal mounted low range microgravity accelerometers, a tri-axis high range accelerometer, a solid state recorder/programmer sequencer, and pressure and temperature sensors.

The tests were conducted using the Gravitational Plant Physiology Laboratory Centrifuge of the University City Science Center in Philadelphia, PA. The launch-powered flight steady state acceleration profile of the Shuttle was simulated from lift-off through jettison of the External Tank, which occurs at the maximum axial acceleration load in the ascent trajectory of approximately 3.0 g's. Additional tests were conducted at twice (2X) the nominal Shuttle predicted powered flight acceleration levels (6 g's) and an over-test condition of four times (4X) the powered flight loads to 12.6 g's.

The present test program has demonstrated the value of conducting ground tests to verify GAS payload experiment integrity and operation before flying on the Shuttle. This test philosophy will provide the maximum return of zero g data from the GAS program.

1.0 INTRODUCTION

Payload 559 will be flight ready for a Get Away Special Cannister in 1989. The original payload consisted of three basic experiments: the prime experiment (No. 1), Mr. Ivan Vera's Membrane Casting Apparatus, two protein crystal devices experiment (No. 2) sponsored by the Bioprocessing and Pharmaceutical Research Center (BPRC) in Philadelphia, PA, and a protozoa growth experiment (No. 3) sponsored by the Hispanic Community. Acceleration ground tests using a centrifuge were conducted on the ITA Standardized Experiment Module (ISEM) which consists of an aluminum aerospace structure and support avionics (power supply, recorder/sequencer, low and high range accelerometers and pressure and temperature sensors) as shown in Figure 1. Experiments 2 and 3 were mounted to the ISEM during the ground tests, however, Experiment No. 1 was not

available and consequently a mass simulator was utilized to ballast the payload to 200 lbs. P/L 559 will be reconfigured from the above test configuration due to Experiments 2 and 3 being dropped by their sponsors.

2. ISEM AVIONICS

The following support avionics described below were integrated into the basic ISEM structure for the acceleration test program.

- 3 Schaevitz low range ±0.25 g accelerometers
- 1 high range ±20 g three axis Entran accelerometer
- 1 0-20 psia Kulite pressure transducer
- 1 Tattletale recorder/data logger
- 1 Onset computer/recorder/data logger/sequencer
- 6 Yardney silver zinc LR90 cells
- One stainless steel battery box

In addition, signal conditioners and junction boxes were fabricated and mechanically integrated to the structure. The purpose of the signal conditioner/junction boxes is to provide commands, distribute power, and record data.

3.0 TEST PROGRAM DESCRIPTION

The test program was designed to simulate the Shuttle launch/powered flight steady state acceleration profile. The launch profile was simulated out to approximately 530 seconds which corresponds with the separation of the External Tank and an axial load of approximately three (3) g's. The Shuttle acceleration levels are less from this point on in the trajectory to orbit. The ISEM was mounted to the centrifuge using the standard GAS interface. The unit was repositioned on several runs such that the loads could be applied to three orthogonal axes. Functional tests were performed on each experiment and each subsystem of the avionics after each centrifuge run.

4.0 FACILITY DESCRIPTION/TEST SET UP

The University of Pennsylvania Gravitational Plant Physiology Lab centrifuge is a dedicated acceleration research facility that was used for the program. Figure 2 presents a photograph of the centrifuge showing the ISEM mounted inside the test gondola. It should be noted that the ISEM was mechanically mounted to an adaptor plate on the gondola identically to the attachment scheme defined by NASA for Shuttle operations, i.e., a 19 inch bolt hole circle. The centrifuge contained accelerometers mounted adjacent to the top and the bottom of the ISEM.

A control room was located adjacent to the centrifuge room where TV monitors and VCR recorders were used to observe and record the module during the run. In addition, the instantaneous

acceleration levels were recorded for "real time" assessment of the test results and the final data analysis.

5.0 TYPICAL RUN SEQUENCE/TEST PROCEDURE

Pre-test photographs were taken of the payload prior to each run. Functional tests were then conducted on the avionics and the experiments. Voltages of each sensor were monitored and recorded. Pressure and low range accelerometers were stimulated and the responses recorded. The experiments were energized and the motors run in each direction.

The recorder-data logger was then activated and the centrifuge started. The ISEM module was observed by the TV camera mounted on the hub of the centrifuge, and the instantaneous real-time read out of the centrifuge accelerometer levels were monitored and recorded.

After the centrifuge was shut down and ceased to rotate, the onboard recorder was de-activated and the ISEM visually inspected. Post test photographs were taken to document structural integrity of the module and components. Functional tests were then conducted again on each avionics component, and on the experiments to verify that they operated properly after being subjected to the acceleration environment.

The module was then taken out of the cradle to change the orientation for the next run as shown in Figure 3 and the entire procedure was repeated.

6.0 TEST RESULTS

Figure 4 presents the results from the first test which was a standard Shuttle (3 g) run. The difference in readings between centrifuge accelerometers 1 and 2 was due to location differences on the arm. The ISEM accelerometer shows good agreement with the centrifuge data after being biased to one g. Figure 5 presents data for the ramp function to 12.6 g's (4x Shuttle loads). It should be noted that the ISEM flight accelerometer (Entran tri-axis) tended to drift during the entire test series.

A comparison of the Shuttle acceleration profile from flight data with two centrifuge runs (1X and 2X Shuttle) using the ISEM data is shown in Figure 6. This comparison demonstrates that centrifuge facility provides a good simulation of the Shuttle acceleration flight loads.

All of the avionics performed well during this test program with the exception of the three axis Entran accelerometer which tended to drift. As a result of this test program, the Entran accelerometer is being replaced on Payload 559.

The BPRC crystal growth experiment showed a potential failure mode which has been corrected for the actual flight. Finally, the power supply provided ample power for the test program, however, the Yardney cells "leaked" when subjected to the 12.6 g acceleration ramp function. This points out that orientation of these cells is important when designing a GAS payload.

7. CONCLUSIONS

The following conclusions were reached as a result of this test series:

A. The centrifuge facility provided a good simulation of the steady state acceleration load profile during the launch ascent portion of the Shuttle trajectory.

B. The ISEM structure, avionics, and MPS experiments survived the max loading condition, (12.4 g's) and all electronics and mechanical components successfully operated and passed functional tests after the environments.

C. The three axis high range accelerometer to monitor launch and re-entry loads was found to drift to an unacceptable level during the test program. Accordingly, the accelerometer will be replaced prior to shipment of the payload.

D. A potential failure mode of one of the MPS experiments (protein crystal growth) was identified and subsequent modifications made to the hardware to eliminate the potential failure mode.

8. CONCLUDING REMARKS

The present test program has demonstrated the value of conducting ground tests to verify GAS payload experiment integrity and operation before flying on the Shuttle. This test philosophy will provide the maximum return of zero g data from the GAS program. Subsequent additional tests are planned for Payload 559 after reconfiguring some of the experiments. The reconfigured payload will be subjected to the Shuttle vibration environment prior to shipment to NASA.

9. ACKNOWLEDGEMENTS

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The ground test program was partially funded by the Commonwealth of Pennsylvania's Ben Franklin Seed Grant program.

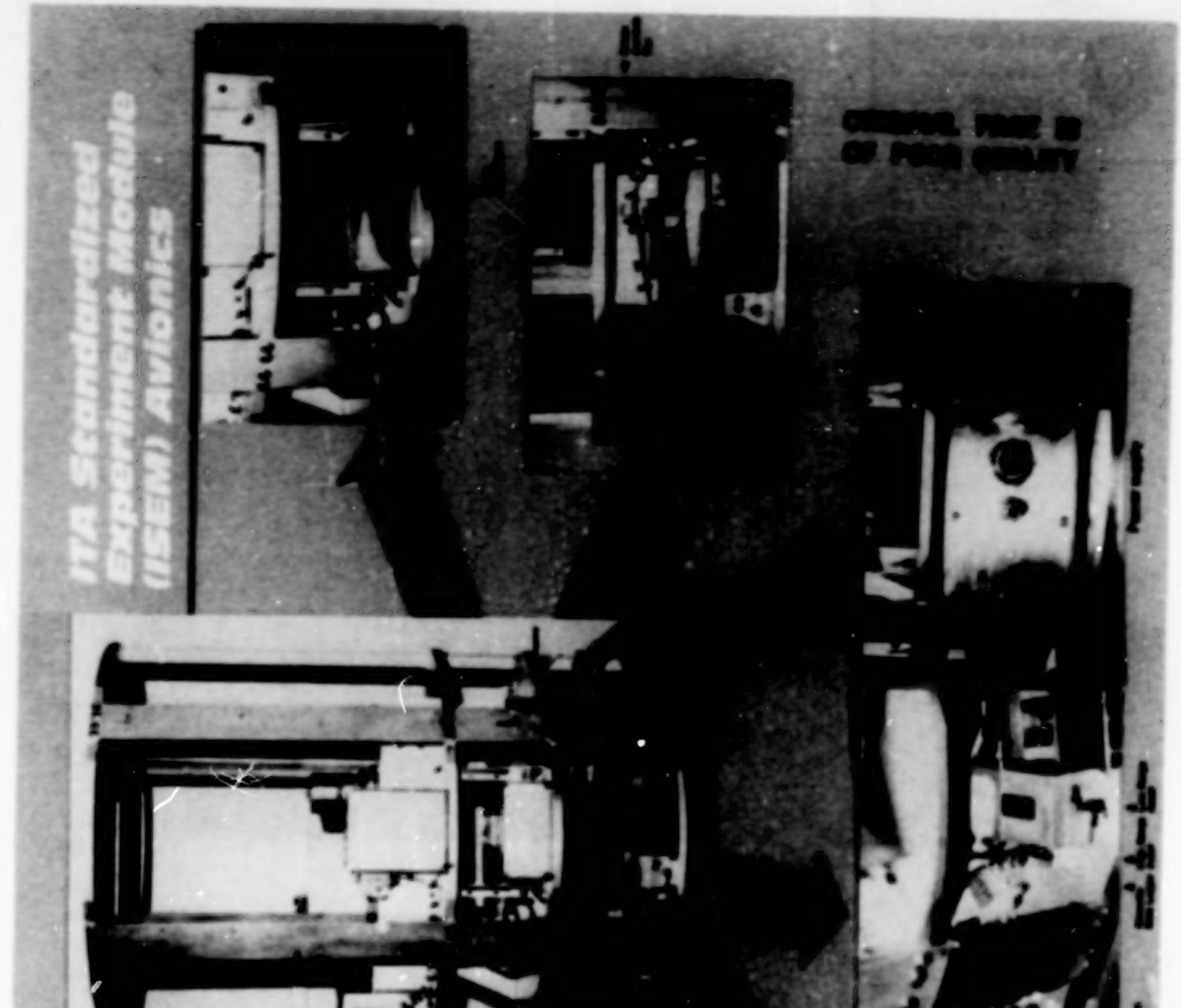
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Figure 1

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Figure 2 Centrifuge with Test Gondola

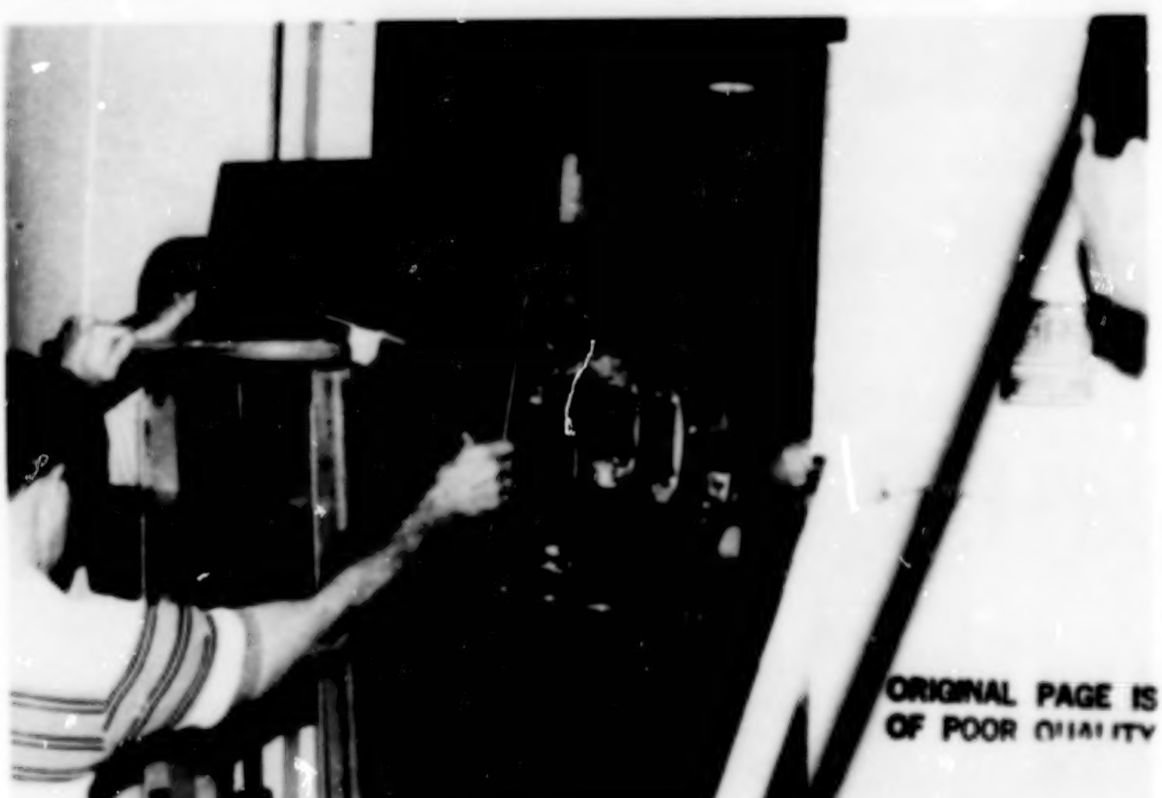

Figure 3 ISEM Being Repositioned to Change Load Vector

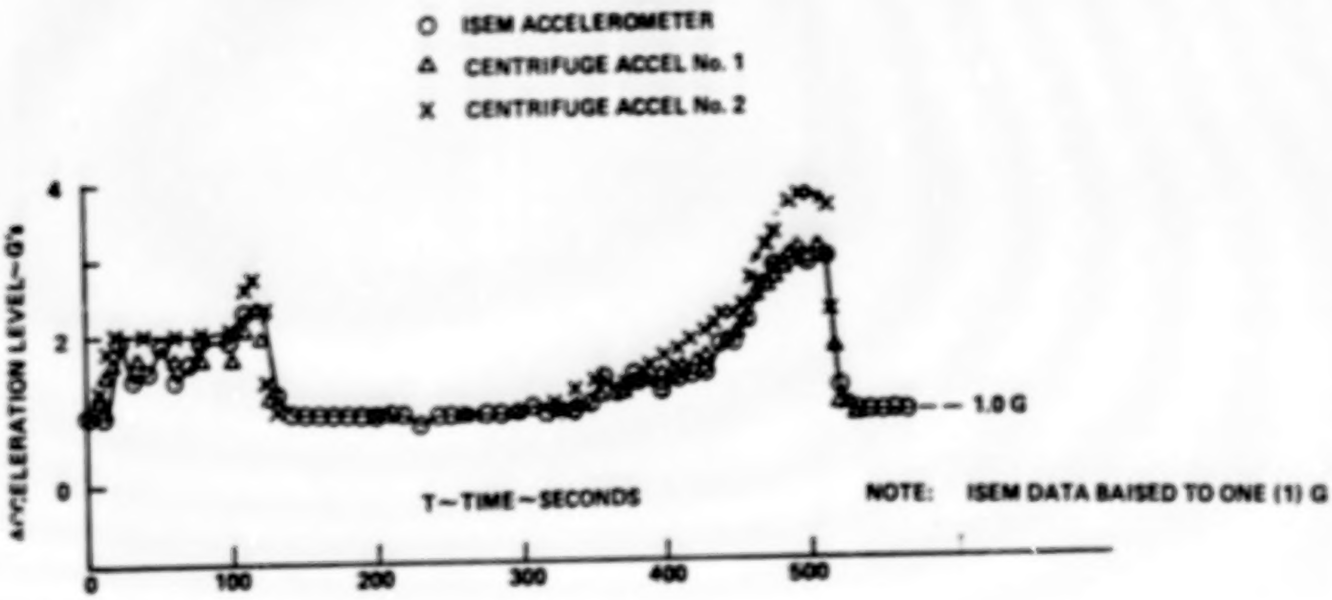

Figure 4. Centrifuge Test Data for Normal Shuttle Loads

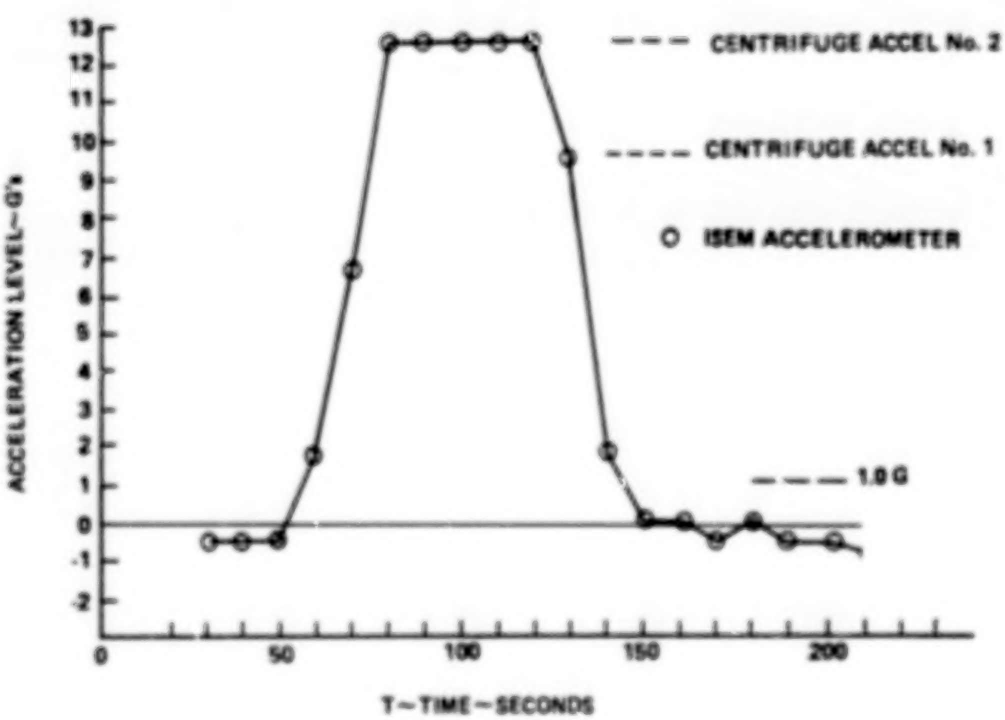

Figure 5. Centrifuge Test Data for 4X Shuttle Loads

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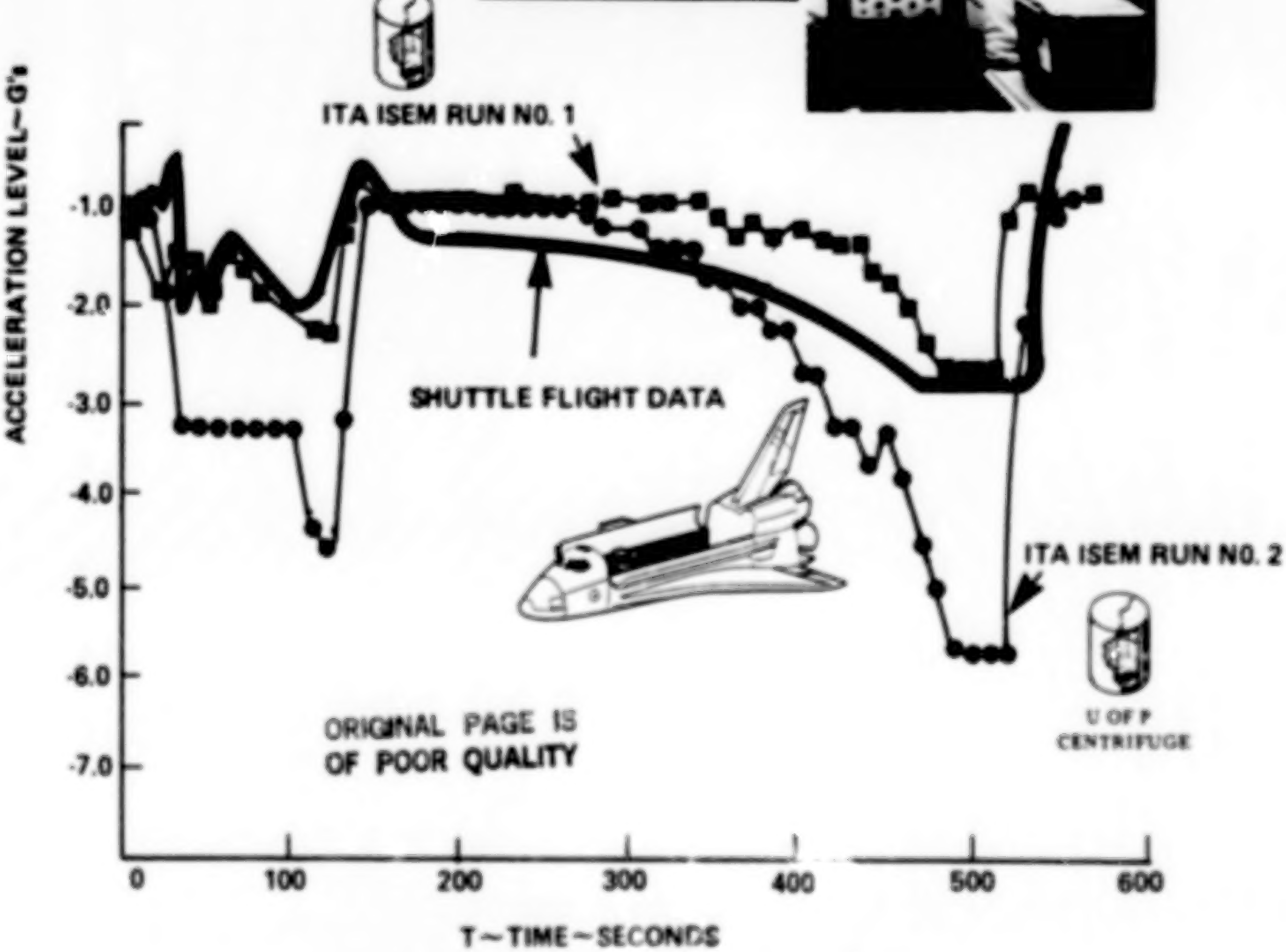
COMPARISON OF U OF P CENTRIFUGE GROUND TEST DATA WITH SHUTTLE FLIGHT DATA FOR LAUNCH ASCENT ACCELERATION PROFILE

U OF P CENTRIFUGE



DATA SOURCE: ITA CENTRIFUGE TESTS, JULY 1986

Figure 6

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UTILIZATION OF SPRAY ON FOAM INSULATION FOR MANNED AND UNMANNED SPACECRAFT AND STRUCTURES

BY

Thomas M. Hancock III

ABSTRACT

This paper will explore the idea of using spray on foam insulation as a passive thermal and micrometeorite protection system. Examples of its application, utilization and benefits are addressed.

When the United States begins the development of large space structures (Space Station, Lunar base, Mars missions and large space factories), there will be two requirements common to all these designs: the need for a lightweight and passive micrometeorite and thermal protection system. One such possible solution to both these requirements is a stable, strong type of spray on foam insulation.

The benefits of applying an exterior coating of foam insulation can be:

1. The foam can provide a thermally stable shield that can assist in reducing the strain on traditional space radiator systems. It can also act as a passive thermal guard, allowing a greater fault tolerance if the standard system should fail.

2. The foam can act as an ablative shell diminishing the effects of natural and manmade debris striking the structure.

3. The foam can provide a lightweight passive shield with a general weight of ½ ounce per 1ft2. This is highly attractive from the position of design.

4. Cost: a spray on foam system can represent a significant cost-effective design.

5. Maintenance: the maintenance of such a system will be minimal and simple to carry out.

6. A stable material that does not react when exposed to Earth or Lunar space environment. (The Thermal Blanket insulation originally developed for the Galileo Jupiter mission was found to deteriorate when exposed to atomic oxygen in low Earth orbit.)

When one considers that current solutions to this problem include Armored Skins, Thermal Blankets and Louvers, the obvious and practical applications of foam insulation in fulfilling each of these requirements represents a simple, complete and cost-effective method for meeting the requirements of thermal and meteorite protection.